JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLIX, NO. 1. 75TH YEAR. JANUARY, 1900

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

Mechanical and Engineering Section.

INTRODUCTORY ADDRESS.

BY WILFRED LEWIS,
President of the Section.

[Commemorative Meeting held in Convention Hall, National Export Exposition, Thursday, October 5th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

For seventy-five years the Franklin Institute has devoted itself assiduously to its well-known object, "the promotion of the mechanic arts," but in the performance of this great work it has realized at various times the advantages arising from the concentration of effort along certain lines within its broad and liberal scope.

The constant subdivision of scientific thought into branches whose bounds are more and more rigorously defined is an index of the progress of our age, not that there are more different kinds of science to be studied, but because the fields of research and investigation have so

expanded that the human mind is overwhelmed by the vastness of the whole, and individuals must be content to master thoroughly one small corner of a general division.

The Chemical, the Electrical and the Mining and Metallurgical Sections were consequently formed to meet the demand for more restricted bounds within which the specialists in these departments could carry on their work.

These sections are firmly established and their valuable services have been appropriately commemorated here to the honor of the Franklin Institute. They have records upon which they can look back with pride, and futures full of promise, but the work of the Mechanical and Engineering Section, which I have the honor to represent this evening, has only just begun.

About a year ago, it was suggested that a section of the Institute be organized which would appeal directly to the artisans, mechanicians, draughtsmen, designers and engineers, who form so large and important a part of our population. It was not intended to encroach upon the fields now occupied by the national and local engineering societies, whose members are for the most part engineers in active practice, but to form a society more democratic in its scope, which would welcome all who are interested in mechanical pursuits, regardless of their skill or attainments. Skilled and unskilled mechanics, novices and past masters in engineering were to have a common meeting-ground, where all might be heard, and it was hoped that in the meeting of earnest workers thus brought together, theorists would learn much to their advantage from the more practical men of action and manual skill, while the latter would be equally benefited by a deeper insight into the methods and principles of engineering.

The proposition to organize a section devoted in this way to the interests of the various mechanical pursuits at once met with favor, and the Board of Managers, at its stated meeting of November 9th, 1898, authorized the formation of a "Mechanical and Engineering Section." The inaugural meeting of the section thus authorized was held December 15th, under the leadership of Mr. James Christie,

Chairman of the Committee on Sectional Arrangements, and Chief Engineer of the Pencoyd Iron Works, which has so recently astonished the world by its successful competition with England for the construction of the Atbara Bridge in Egypt. Under his guidance the section sprang at once into active life and work, and there are now enrolled upon its list of members 188 active men, as the nucleus of an organization which cannot fail to be a power for good in this and other communities.

Although not at once a large society, our numbers are, nevertheless, encouraging as a part of the Institute, embracing as it does only 2,000 members, from which we must draw recruits, and we confidently hope to grow as the advantages of membership become more generally known.

To become a member of any section, one must be a member of the Institute, in good standing, and to be such a member it is only necessary to pay the small annual dues, in return for which such abundant returns may be enjoyed.

But it is my purpose to deal more particularly with the work of the section to which this evening is devoted, and to lay before you our special claims to consideration. Every industrial establishment in the city should be interested in our success, and our members would be counted by thousands and tens of thousands if the vast army of workers could be made to realize the helpfulness of mutual education by actual contact with fellow-workers in the same field of interest.

At the inaugural meeting, a code of rules was adopted, similar to those in force in the other sections. The selection of subjects for discussion was placed in the hands of a committee on information, who decided to devote the first stated meeting to Personal Reminiscences of Changes in Machine Design and Shop Practice. This proved to be an almost inexhaustible subject, and much interesting and entertaining information was elicited, some of the members going back fifty years, to the time when railroads and steamboats were in their first stages of development. Since then we have taken up the following subjects, the discussions of which have been reported in the *Journal:* "Travel-

ling Cranes," "The Mechanical Applications of Compressed Air," "The Construction, Operation and Maintenance of Pumping Machinery," and "Hydraulic Transmission, Valves and Packing."

In addition to the regular meetings, at which the above subjects were considered, a special meeting was called in February, to hear an address by Prof. Wm. S. Aldrich, on the U. S. Repair Ship "Vulcan," which played so important a part in the recent war with Spain. Prof. Aldrich was the Engineer-in-Charge on this remarkable vessel, and his lecture, amply illustrated by lantern slides, was full of interest.

The inestimable value of facilities for repairs at sea was clearly demonstrated, and in this was seen the immense latent strength of American forethought and mechanical genius. All honor to the men behind the guns, but they are powerless unless behind them stand the mechanics and the engineers who furnish the munitions of war with which swift and terrible execution can be accomplished. We have shown to the world our undaunted valor, energy and power to destroy, and we are now showing in a greater degree our power to build. Construction, rather than destruction, is the gauge of our real strength, and to none does the nation owe its supremacy more than to its mechanics whom the Franklin Institute has fostered and encouraged for seventy-five years.

But it is not for me to speak of the history of this noble institution, which has been aptly styled a "democratic learned society," and it would be presumptuous to make such an attempt in the presence of one who has been so long identified with its achievements—an engineer of international reputation, who has honored the Institute by his devoted service, and who has been honored in return by the highest office it could bestow—one who has labored for the enlightenment and prosperity of mankind like a true disciple of the immortal Franklin, and whose latest work has put Niagara in chains to serve our needs with the vast power that would otherwise be squandered. It is hardly necessary for me to introduce Dr. Coleman Sellers, who will now address you on "The Progress of the Mechanical Arts in three-quarters of a Century."

THE PROGRESS OF THE MECHANICAL ARTS IN THREE-QUARTERS OF A CENTURY.

BY COLEMAN SELLERS, E.D.,
Professor of Mechanics, Franklin Institute.

[An Address delivered in Convention Hall, National Export Exposition, Thursday, October 5th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

Mr. President, Members of the Mechanical Section of the Franklin Institute, Ladies and Gentlemen:

I have listened with interest to the remarks of the President of this section, Mr. Wilfred Lewis, in regard to the advantages which have resulted from the formation of the several sections within the society, by which those members forming the respective sections can associate and effect an exchange of opinions on matters of common interest, apart from the regular meetings of the society at large.

In looking back to the time when the Franklin Institute celebrated the first half-century of its life, I recall the speakers on that occasion, and regret exceedingly that some are unable to take part in the present celebration. I had the honor at that time to be President of the Institute and presided at the meeting held in Musical Fund Hall. Among the speakers was Mr. Frederick Fraley, who delivered the historical address, he being one of the two survivors of the original founders of the Institute. Mr. Fraley is still with us, and is now the only survivor of those few men who had the good of the mechanic and craftsman at heart when they established what has proved to be among the most successful in its practical results of all institutes of the kind in the world. I regret that the condition of Mr. Fraley's health prevents him from being able to address you at this time, but I know that in heart he is with us, as he has been for the past three-quarters of a century.

The scope of the subject upon which I have been asked to address you merits careful preparation in order to pre-

sent it in a sufficiently comprehensive shape for the limits of a single address. I regret extremely that I have not had an opportunity for such preparation, and can offer, therefore, some informal remarks only, covering a few recollections and observations on the progress of the mechanic arts during the past seventy-five years. The records of the Franklin Institute are the records of much of the progress made during the whole of this time, and in the volumes of its *Journal* you will find abundant evidence of the good work of the earnest mechanics, engineers and teachers who have come together for mutual benefit and in the interest of this society. You will find no better place to note the progress of the mechanic arts than in the account of the work of these citizens of a great manufacturing city in the reports of the committees of the Franklin Institute, and especially the Committee on Science and the Arts, which for many years performed gratuitously what is now largely confided to paid experts. These men did this work of the Institute, and are still doing it, for the common good, without any expectation of other reward than the satisfaction of unselfish interest in mechanical progress.

The greatest advance in mechanics has been manifested since the advent of the locomotive. It so happens that the birth of the modern railroad system is coincident with my own birth. At that time the first railroad was put into operation in England, which development, taken in connection with the advent of the steamboat which preceded it, was certainly the exciting cause of the great industrial advance that has since been made. Previous to 1827 wooden rails had been laid to form roads over which ore was hauled from the mines, and coal was transported in the same manner by animal traction to better advantage than over common roads. Oliver Evans in our own country, and other engineers abroad, had conceived the idea of the high-pressure steam engine, and, with the full understanding of its value, a practical traction engine to use on roads, was one of the first examples of its application. It was after the invention of the road engine that the locomotive upon rails became possible.

The traction engine applied to the railroad was the basis of our present wonderful system of inland intercommunication, and its development has given an impetus to all trades. In fact, the wants of the railroads taken alone would have been sufficient incentive for what has since been done in the mechanic arts, engaging, as it has, the attention of engineers to produce the labor-saving tools required for the improvement and preservation of the railroads and equipment, including the great iron and steel works that supply the rails, bridges and buildings.

Special machinery has been constantly needed to render possible such industries as iron ship-building, bridge and structural work, and the appliances which have been introduced in place of hand labor throughout the industrial world.

The progress of the single industry of machine tool building has, therefore, a most important bearing on this subject, and traced through the many stages of its rapid growth, the development of this one industry would be sufficient to illustrate the progress in mechanic arts during the period in question, and especially what has been accomplished in this country.

The important relation which tools and implements bear to the mechanic arts and, in fact, to all arts and crafts, forms the subject of an interesting tradition which was published in the *Journal of the Institute* by the late Mr. Joseph Harrison, Jr. In his home at Philadelphia he exhibited a painting by Schusselle representing a blacksmith seated at the right hand of King Solomon's throne in his great temple, to illustrate a hypothecal event during the feast given in Jerusalem at the completion of the edifice. To this feast had been bidden the various artisans who had been engaged upon the construction and decoration of the building, those who had helped to shape the gold and silver and carve the ivory and weave the costly hangings that decorated its walls. There also came, unbidden and unrecognized, the swarthy smith, who, forcing his way through the courtiers and the guard to the throne of the king, claimed recognition as the one man to whom was due the creation

of the entire work, for it was he who had forged the tools without which the other artisans could have done nothing. The wise king, recognizing the justice of the claim, gave to the smith the seat of honor.

Antedating the smith of King Solomon's day and the mechanics of all times, the progress of civilization can be traced by the study of the implements used in the daily life of different races of man, and prominent in the progress of the mechanic arts must be counted the tools with which work has been accomplished.

As one instance of progress from primitive methods during the period under consideration, it may be of interest to refer to the construction of one of the first large engines that were built for the city water works in Philadelphia. There is probably no one present who can recall the fact from actual memory, but where our Public Buildings now stand there was once a smaller structure, on top of which was a tank into which water was pumped, and this water was distributed through the then small city below Broad Street by means of wooden pipes of comparatively small size. The engine used in this work was, I believe, of the Oliver Evans type of high-pressure engine, the cylinder of which was cast in New Jersey. The boring bar used in boring out the cylinder was of the crudest character, operated by hand by means of levers attached to it, so that men walking around the cylinder could propel the cutting tools, and gradually force the cutters on the boring bar, through the cylinder, until it had been turned out approximately true. After that the inner surface had to be filed to a sufficient degree of smoothness. Probably a month was consumed in this operation of boring the cylinder. As I shall take occasion to mention, the subsequent improvements in machine tools have changed the process of cylinder boring from an effort of days to the work of a few hours.

It may be of interest also to note that when the engines were erected and the boilers put in their place at this Center Square Station, the latter were found upon test to be insufficient for their purpose. Oliver Evans had specified

the length of the grate bars and the width of the furnace to be used, as also the length of the boilers, which were of the plain cylinder type, but the wise men of the city government believed that they could do better by making the boilers much longer than he had suggested, and they were so constructed. Upon their failure to do the work, Oliver Evans, who was in New York, was sent for in haste to correct the difficulty. His message to those in charge, enforced by his presence afterwards, was that they must cut off 10 feet from the length of each boiler. This seemed a strange proceeding, but he soon explained to them that the extra length which they had added to his prescribed dimensions was acting as a condenser to re-convert steam into water, inasmuch as the heat of the furnace could not extend the whole length of the boilers as they had been built. Upon cutting the boilers down to their proper size so the heat could extend over their whole fire surface, they proved sufficient for their work, and continued to operate as long as this primitive water plant was in existence. I have this story from those who were living at the time.

I hope I may be pardoned for alluding here to some events in my own experience as a mechanic in order to justify my authority as a historian. From earliest childhood my interest has been led in the direction of the mechanic arts. My first knowledge of physics came from my father, through his instructions and experiments for my benefit before I had fairly passed out of the stage of infancy, for I was but seven years old when I lost so able a teacher. As a schoolboy most of my holidays were spent in his machine works at Cardington, near Philadelphia, where I had abundant opportunity to not only know what was being done at that time, but I had from my seniors the history of what had immediately preceded my personal observation.

My acquaintance with the rapid advance in the railroads of America, and in the motive power on the roads, dates from the time when the building of locomotives was undertaken in my father's shops, immediately after Matthew Baldwin had started his works in Philadelphia. When I was 19 years of age I accepted service as draughtsman

in a rolling mill in Cincinnati, where rails were being made for the roads then projected through the Western States. The rails used at that time, which were called strap rails, were flat bars of iron about 3 x 1¼ inches in section, with oval depressions rolled into the face to receive the head of the spikes driven through the rail to fasten it to string pieces of wood. They were punched at each one of these depressions, which marked the location of the spike hole. At that time the most common accident on the railroads was one unknown now, namely, "snake heads," as they were called, when the strap rails, by the action of the wheels upon them, would curl up, drawing the spikes from the wood, and often piercing the bottom of the car, and not infrequently killing or injuring passengers.

After my experience in the rolling mill, where I acquired a knowledge of the wants of the railroads, I was engaged for seven years in locomotive building, first in constructing engines for the Panama Railroad, in connection with one of my brothers who was the inventor of a locomotive for ascending inclined planes. The late John C. Trautwine was the Consulting Engineer of the Panama Railroad, and it was on his recommendation that these engines were ordered, in the belief that some heavy inclines would have to be overcome in passing from the Atlantic to the Pacific Ocean at Panama, although these inclines were avoided, and the engines eventually used in the construction work merely.

Subsequently I entered the locomotive works of Niles & Co., of Cincinnati, as foreman for five years until 1857, when I accepted service as Chief Engineer for William Sellers & Co., of Philadelphia, then, as now, engaged in building machine tools. Thirty years' active experience in machine tool building enables me to speak from a full knowledge of this industry and what machine tools have done for the advance of the mechanic arts. When engaged in locomotive building in Cincinnati, I introduced a number of improved methods, but was hampered continually for the want of machine tools powerful enough to do the work as I desired it done, as well as for the want of special tools

not then available. At that time in the Eastern cities certain machine tools were being built with success and were doing far better work than it was then possible with tools built in a branch of the locomotive works where I was engaged. The firm of Niles & Co. had, however, some reputation even then as builders of machine tools and sugar machinery, but it was not until the retirement of the original founders of the house that the works became devoted wholly to the machine tool business. At the time I speak of, slotters, horizontal boring machines and lathes of various kinds and quality were built in America after the introduction of the planing machine, the first one of which was probably introduced into the city of Philadelphia some time about 1830.

The early machine tools were of the crudest workmanship, and most of the lathes were made partly of wood. In fact, the transition from wood to iron in the construction of machinery was in progress during the early part of this century, and the formation of the tools themselves and much of the machinery built at that time involved the conversion of structural shapes required for wooden machines into similar shapes in metal. In the first change from wood to metal, architectural shapes and ornamentation were considered desirable to make machine tools and other machinery meet what seems to us now the rather barbaric taste of those who were to use them. The same might be said of locomotives, which almost up to the sixties were elaborately decorated with paint, polished brass and scroll work. England gave us the first good machine tools, and set the example which has tended to simplicity in design. To that country we owe much that is valuable, not only in the direction of self-acting machine tools, but also in the various appliances for improving the character and quality of work to be accomplished. Thus, Sir Joseph Whitworth, one of the earliest makers of superior machine tools in England, aimed at utility and not ornamentation in the improvement of his products. It was he who introduced surface plates for producing other plane surfaces by means of the scraper; that is to say, after a surface had been made

comparatively true on the planing machine, it had yet to be brought to a commercially true plane by a process of scraping off the higher projections, until, when tested by one of the Whitworth surface plates, it seemed to touch at intervals of not more than $\frac{1}{4}$ inch.

After scraping had come to be recognized as the only means of making true plane surfaces, there followed, unfortunately, a form of deception that exists, I am sorry to say, not only in America, but still more prominently in some of the copies of American machine tools produced abroad, namely, the practice of scraping the surface without any special regard to the purpose for which the operation is intended, but rather to give it the appearance of having been carefully fitted, and the surface so produced was very aptly called by the late Mr. William B. Bement, of Philadelphia, "bedquilt scraping." The parts touched by the scraper in this imitation work are very often not irregular in design, but constitute a set figure or pattern which cannot deceive the eye of those familiar with good work.

Long before the time of the International Exhibition of 1851, America had begun to take her place in machine tool building, under a clearly distinct line of thought that was for a long time not appreciated in other countries. When visiting England, in 1884, I was shown a copy of an American planer adapted to planing the stub ends of connecting rods for locomotives, there being two sets of uprights and two cross-heads with four tool-holders adjustable in position to enable both ends of two connecting rods to be planed simultaneously. The American tool from which the idea was taken has its cross-heads facing one another, and the table is speeded to run back and forth at the same rate of cut. By this means the machine is made to take a cut at each forward and backward movement of the table. The English machine had its tool-holders facing in one direction, and all four cuts were taken at one and the same time only when the table was running forward, no work being done on the back stroke. The power of the American machine was therefore double that of its English copy, all other things being equal, and the maker was astonished when this was pointed out to him.

This one example shows how difficult it is to copy the machinery of another country if the copyist does not grasp the controlling idea of the mind that gave life to the original. Instances of this are found in many other directions where American contrivances, having obtained a world-wide reputation, are less efficient in the foreign copy than in the original production.

The planing machine is an invention well within my own experience. In the beginning it had the platen, upon which the work is fixed, dragged backwards and forwards by a chain. The first planer that William Sellers & Co. purchased and put into use was one of this chain pattern, and one was introduced in my father's shops when he undertook to build a locomotive in 1834. At the time of the Vienna Exposition, where machine tools from Philadelphia were exhibited, the engineers sent by the British Government to Vienna to note the progress that was being made noticed the broad feed cut on all the planing machines, lathes and tools that came from all parts of America, and remarked upon it as "producing good effect," as "looking well," etc., as if it were for appearance only, not knowing that it was a principle that had been established in America, thoroughly understood not only by the managers of the works, but by workmen all over this country, and universally adopted as necessary to good work.

I have already referred to the slow process of boring cylinders for pumping engines. When the early locomotives were built, for example, in the Niles Works, in 1856, the boring of the cylinders was done on a 36-inch lathe with a horizontal boring bar, and without any knowledge as to the theory of boring in order to produce the best results. It always took two days to bore the cylinder of a locomotive of the size in use at that time, and I think the largest cylinders were not over 15 inches in diameter. In Philadelphia, when Baldwin's had advanced to a very large establishment, they still bored the locomotive cylinders in the same way. It was not until shortly before the Centennial Exhibition of 1876 that attention was turned towards the utilization of a theory that had obtained in

limited practice some years before as to the improvement in boring metals, the idea being that the quickest and best work can be done in boring by making the roughing cut with a fine feed, removing as much metal as possible by depth of cut, and making the finishing cut with a very broad feed but light cut that would let the cutter pass through the hole to be bored as quickly as possible so as not to wear the cutting edge in passage. That principle was first introduced when Mr. Asa Whitney, of this city, discovered that chilled cast-iron car wheels could be made to compete with the best wrought-iron ones and do a greater mileage. If the wheels cast in an iron mould were not allowed to cool naturally, but taken red hot from the chill, were put into the annealing furnaces and brought up to a heat a little below the melting point, and then allowed slowly to cool, they were found to be free from all internal strains, while wheels taken red hot from the mould would burst into three or four pieces in cooling, showing that there was violent internal strain in metal cast in that way under the tension of the heavy chill on the outside of the tread of the rim. The problem of boring chilled wheels was solved by taking advantage of the fine roughing cut and coarse finishing feed. Mr. Whitney desired to have wheels made interchangeable in their fit on the standard axles, so that when a wheel was fitted on an axle at a workshop in Philadelphia, another wheel could be furnished to fit that same axle at any future time, and just as well as the first one.

When the late Mr. Hudson had charge of the Rogers' Locomotive Works he applied to the firm of William Sellers & Co., to have a special locomotive cylinder boring machine designed and built, saying that he had seen a boring machine designed by Mr. Grant, of the Grant Locomotive Works, capable of boring a 19-inch cylinder in nine hours. The matter was referred to me, and when I came to calculate the theoretical time required for boring a cylinder of the size named, on the supposition that the speed of 16 feet per minute might be used in making the cuts, with a fine feed and a deep cut for the roughing cut, and a shallow cut and a much wider feed for the finishing cut, I found that the

estimated time amounted in all to only three hours, and named three and a half hours as not only possible, but what might be guaranteed as the productive output of such a machine. An order was given for this machine, it being understood that it was not only to bore the cylinders, but to counterbore the ends for the clearance of the piston, to cut off the sinking head and face up the flanges at each end of the cylinder. When completed, the first test was made with a 19-inch cylinder of hard close metal. This was bored in three hours and twenty minutes, exclusive of the time of setting the cylinder, which was not much on account of the peculiar arrangement of the machine, and the facility with which the cylinder could be put in place for boring. In this case the cylinder stood still, while the boring bar travelled lengthwise, carrying the cutter head with it, and upon the two face plates of the driving heads of the machine were arranged automatic slide rests that faced off the flanges. In this design there was no guesswork, as the principle of fine feed and deep cut on roughing, with very coarse feed and shallow cut for finishing, was in common use in all operations of boring, turning and planing metals, with exact knowledge as to what result was obtainable when the possible speed of cut per minute had been predetermined for the hardness of the metal to be tooled.

Since the time when I first related the incident of the rod planer in a paper published by me in the *Engineering Magazine*, in 1892, even this tool, useful as it is, has been superseded almost wholly in locomotive works by improved milling machines. It is not my province to detail step by step the advance that has been made in machine tool building, but, as stated at the outset, I wish to make this industry illustrate the advance in the mechanic arts, and in connection with it I must call attention to the relative condition of the skilled workmen in America and in other countries. We owe much of our progress to our common school system, to our freedom from precedent and to our just patent laws. I do not wish in the slightest degree to decry what has been done abroad, for I myself have been a close stu-

dent of the progress of the mechanic arts the world over, and have been only too glad to recognize and avail myself of all that is good and worth adopting, assuming at the same time that improvement is possible and absolutely necessary in many cases to adapt the machinery designed abroad to the conditions that obtain in American workshops. The tendency to standardize everything is peculiar to this country. Builders of locomotives in America adopt standard sizes and types of locomotives, and are thus able to manufacture such to great advantage. Railroads in America are willing to take from the builders what has been shown to be good and effective, and when the same kind of machine is to be duplicated many times, the maker can afford to invest heavily in special gauges and special tools that decrease the amount of manual skill required in laying out the work or working to drawings. The first time a piece of work is done, whether it be small or large, simple or complex, more time is spent upon it than after the workmen have become familiar with its construction, and certainly more time than would be required after special appliances have been invented and made to cheapen the product, especially when the men are paid for their work according to the quality and quantity turned out, and not by a fixed wage per diem. I allude to this because I know it is the custom of foreign railroads to submit to builders in England and America specifications for engines that cannot compete in economy of construction with those that are built in quantities in the way that I have just mentioned. It is the recognition of this fact that is now opening the markets of Europe to American locomotives as they are built and as they are used in America. A celebrated builder of locomotives in England told me that the rules of the Board of Trade and Parliamentary regulations for the safety of the people crowded their locomotives with useless appliances. A close observer of railroad machinery, who is familiar with the principal railroads in the world, has stated that if a locomotive builder abroad is given a new problem, such as to construct a hill-climbing freight engine, or a goods engine as it is called abroad, or even an express passenger

engine for mountain districts, a completed machine may be the result that is a model of strength and durability, but inaccessible in the extreme when ordinary repairs are required. It is easier to take out the cylinders in an American engine and replace them with new ones than it is to reset the valves on the type in general use abroad, where the valve chests are crowded together under the smoke-stacks as though they would never require adjustment or resetting. The persistency evinced in adhering to the crank axle in English engines, in spite of its weakness, is one of the matters not understood in this country. Give accessibility to the valves, and ready access to all the parts, and the whole engine will be better cared for by those in charge of it.

It has been the scientific methods introduced by the managers of the railroads, aided by the skill and perfect equipment in their workshops, that have made those great railway systems what they now are. They must exercise the utmost caution in all that they undertake; every alteration or deviation from adopted standards involves so many pieces that must be changed. In regard to the simple matter of making brakeshoes for the cars, and boxes for axle journals, I know from my own experience that it was not until the introduction of machines for moulding these pieces accurately that the best results could be obtained and the parts made exact and perfectly interchangeable. Every invention, whether it be in the foundry or in the machine shop, is cumulative, and has its effect upon other trades, and through our ingenuity and progress we have now reached a point when the whole world looks to America for certain work which it seems cannot be done to equal advantage in other countries.

Dr. John Anderson, then in charge of the Woolwich Arsenal, England, was sent to this country to visit the Centennial Exhibition in 1876, and besides acting as one of the judges of the machine tool exhibit, he made an official report as British Commissioner to both houses of Parliament. Prominent in these reports there will be found one on "Machines and Tools for Working Metal, Wood and

Stone at the Philadelphia Exhibition," in which the following statement occurs:

"Great Britain certainly can claim the credit of having been the birthplace of modern machine tools, and has done wonders in raising the mechanical standard of perfection, and her influence for good in the advance of civilization thereby is incalculable; but when we consider the enormously greater area of the American continent, it is a matter of vast importance that tools have taken such a hold of the American mind, which will influence the civilization of the Western world for ages to come, and will exercise a powerful effect, not only on that continent, but on Australia, China and the world generally." This, therefore, has a profound significance which can scarcely be overrated. Again he said: "The display of machine tools made by the United States was so vast that only the more salient points can be noticed in a brief report. It showed certainly that the past century has not been passed in idleness, and, judging by the enormous stride made by them during the past few years, it showed that they have been intelligent students of the best European authorities. It is true to say, however, that the Americans, as a rule, are not copyists; the inventing of clever devices and tools for saving labor seems to be their natural forte, and worthy of the old stock, probably quickened by the peculiarly favorable circumstances under which they live. It was the display made in this section which most conspicuously brought out the enormous strength of America as a producing power. More than a hundred exhibitors had each a large exhibit that commanded the admiration of all who took the trouble to examine them in detail. In this vast array were machines for all purposes, small arms, ammunition, sewing machines, clocks, watches, and all the branches of machine-making and engineering, and almost all were finished in a style superior to that of any former exhibition."

In the engineering practice of the first quarter of this century, scientific methods did not obtain. There was little technical literature to help the designer, and the best results which have made American ingenuity appreciated the

world over were brought about through careful experiments and earnest effort on original lines. The history of the steam engine, so far as the American types are concerned, was clearly not the outcome of the books, for what is thus taught under the head of thermo-dynamics is really a description of what had been accomplished, rather than the cause of the development. The need of technical education was early felt, but the want was not supplied until the generosity of individuals rendered the foundation of technical schools possible. The Government cannot be looked upon to aid in such institutions in the United States as it can in England, yet up to 1884 in London there was no technical school in existence that in any way compared with those at Hoboken and Boston in this country, besides which engineering is now taught in our universities. At a dinner given to the members of the Institution of Civil Engineers, in 1884, Sir Lyon Playfair, in responding to the toast of, "The Universities of Scotland," after those of England had already been discussed by able speakers, astonished his audience by refusing to speak to the toast directly, and entered a strong plea for technical education in England such as existed at that time in the United States. He said they should not look to Germany and France for the examples of technical schools, but across the Atlantic, where those speaking their own language had already put into practice what England had so long needed. While the speaker was doubtless correct as to the wants at that time in Great Britain, the technical school of South Kensington was then being organized, and the guilds of London had contributed freely toward its support. Good work had been done by this and other schools, and by the trade schools that have been established in various parts of England.

We are long past the period of empirical work. The steel makers and iron founders now depend upon metallurgists to guide them, while every well-equipped machine shop in the country must have its staff of educated men who are able to reinforce the practical knowledge of those engaged in manufacturing by exact mathematical methods

that in the early stages of our profession were limited to simple arithmetic.

As indicative of the necessity of education on the part of the working classes, I have known instances in which labor-saving machinery that was cheapening the output in a particular class of hardware, when introduced in America, into England, failed entirely and brought discredit to the member of the firm who had advised its purchase. A gentleman interested called upon me afterwards and solicited letters enabling him to visit some of the industrial establishments in the United States. Upon his return from these places he told me that all that had been said about the character of the work done by the machinery in question, not only had been confirmed, but that its merits had been underestimated. He said, however, that in his opinion, it was impossible to utilize it to advantage with the workmen in England, owing to trade prejudice and trades union regulations. What the peculiar conditions were I am unable to say, but what I wish particularly to impress upon my hearers in this respect is that in his opinion the difference in the character of our workmen and workmen of the same trades in England is wholly due to the better education of the Americans, who are fully two generations ahead of those abroad. It is perfectly evident that it is impossible to raise the standard of work by means of labor-saving machinery unless the workingmen themselves will see the advantage derived from their ability to do more and better work, and thereby obtain better wages. This is particularly the case when they are called upon in this country to operate machines that do not require constant attention, but where it is possible for one man to attend several machines and earn higher wages than he possibly could if compelled to stand idly watching a machine that required but a small portion of his time to operate. There would be no inducement to contrive automatic machinery unless those who use such machinery are able without prejudice to take advantage of the saving in labor attainable thereby.

Ship-building all over the world, since the first iron vessels were launched, shows by the constantly improved out-

put the wonderful progress in scientific knowledge, and in manual as well as technical skill. The great fighting machines for the ocean have been improved with astonishing rapidity. This year our own output in that line has for the first time been tested and found good, when handled by men of whom we as a nation may feel proud. The nations have been increasing the power of their fighting ships year by year, adding new improvements in machinery, new means of resisting attack from other ships, new guns and newer projectiles to pierce the new armor plate, and let us hope with decreasing opportunity to bring the results to actual test in battle. In our own recent experience, practice at great cost found our trained marine force better equipped for the operation of these fighting machines, and in the far East and in the West Indies our guns swept a maritime power out of existence with upon our part scarce the loss of a man.

In working iron and steel the introduction of the Whitworth forging press marked an important advance compared with the costly steam hammers, and hydraulic presses became absolutely essential in perfecting the American type of link and pin bridge construction. Some of the forgings required for the 5,000 horse-power dynamos needed by the Niagara Falls Power Company could not have been executed by means of any existing steam hammer in this country or elsewhere, and the Bethlehem Steel Company were the first to introduce this system of forging on a large scale. Forging by pressure in place of impact by hammers enables the force required to cause a given deformation of metal to be accomplished with the least expenditure of power and greater exactness, as was soon manifested in the readiness with which hollow shafts were produced. About 1893, the work at Niagara Falls called for steel rings of absolutely uniform density, having an outside diameter of 11 feet 4 inches, with a width on the face of approximately 50 inches, and a thickness of over 5 inches, which necessitated the use of a press of greater capacity than any heretofore erected. The press at Bethlehem, combined with the Whitworth system of compressed steel ingots, was taxed to its utmost to make what

was needed in this case. It is interesting to note that this work was the first product of machinery introduced mainly to furnish armor plates and the massive steel forgings needed for our modern ships of war.

The plant of the Niagara Falls Power Company offers evidence enough of the remarkable progress that has been made, not only in the mechanic arts, but in the high scientific ability required to design machines that had no precedent in size or in exact requirements as expressed in the specifications predetermining each requirement as to the results to be accomplished. Thus the designers of the dynamos were called upon to guarantee an output from each unit of power with so high an efficiency that all the magnetic and electric losses in the machine would not amount to over 2½ per cent. This requirement was fulfilled, and when subsequent machines were installed, the result was even more favorable than in the first instance. The final result is the crucial test of all progress, and certainly we have in those of our industries which require mechanical skill sufficient evidence of the marvellous progress that has been achieved during the past seventy-five years.

As I have taken occasion to mention the work at Niagara Falls, which has engaged so much of my attention, it may interest those who are not familiar with the results of this undertaking to hear something further in regard to it. At Niagara Falls we had for the first time to construct a tunnel that would be adapted as a tail race to the development of 100,000 horse-power. The International Niagara Commission had decided that 5,000 horse-power was to be the unit, and the plant was accordingly laid out on this basis. It was assumed that water-wheels could be made of that capacity and could be placed 150 feet below the level of the dynamos to be operated, where, as one of the Commissioners suggested, the length of shaft would be about the same as between the propeller and engines of an ocean steamship. In the practical solution of this problem we were obliged to have similar thrust bearings to guide the shaft, but the construction of the turbines is such that the water under the upper wheel of the two in the case is made to support

the whole mass of about 160,000 pounds. The dynamo at the upper end of the shaft, therefore, practically spins on a cushion of water with only a pressure of 3,000 more or less on the thrust bearing rings, according to the variations in the velocity as the power developed is increased or decreased.

It is too large a subject to permit me to refer in detail to all of the work that had to be done at Niagara Falls, but I want to say that, while our constant effort has been to interest the manufacturers of machinery to make designs that they could guarantee, a great deal of designing has been necessary by the engineers of the company, most of which was experimental, and that no failures should have been experienced is most satisfactory, when I realize how little precedent we had to guide us, and the risk attending the solution of the problem as it was presented to me.

The first three turbines that were installed in accordance with the design of the builders had to be materially altered, and I have introduced improvements of my own invention to enhance their efficiency as far as the shaft transmission is concerned. These modifications were made in the five units that were subsequently installed, and without any change in the water-wheels, the efficiency was increased so that they delivered 5,500 electrical horse-power each, instead of 5,300 horse-power, which was the output before the changes were made.

As now constructed, all the electrical and magnetic losses in each of the dynamos aggregate but 2½ per cent., and you can judge what the efficiency of the water-wheels must be when those which, at 75 per cent. efficiency, would give 5,300 horse-power, are now driving dynamos that deliver 5,500 horse-power without any changes in the wheel, but only such alterations in seemingly immaterial parts as the design of the connection between the water-wheels and the dynamos.

As regards the utilization of the power being developed at Niagara Falls, it may interest you to note that we hope shortly to have ten dynamos running, each of 5,000 horse-

power nominal capacity, but actually capable of delivering over 5,000 horse-power each.

The first industry established in connection with the plant was a paper company, which required 7,200 horse-power, but it installed its own wheels on land of the Power Company, and utilized the latter's tunnel and canal facilities. Next followed the Pittsburg Reduction Company, which takes 8,550 electrical horse-power for the manufacture of aluminum. The Carborundum Company, for making abrasives, takes 1,030 electrical horse-power. The Union Carbide Company, 5,000 electrical horse-power, for the manufacture of carbide of calcium. The Niagara Electro-Chemical Company, making peroxide of sodium, that is, metallic sodium, takes 400 electrical horse-power. These and other works now in operation or being installed will utilize, possibly by the first of next year, a total of 41,000 horse-power. Most of these establishments are electro-chemical or metallurgical in their processes, and have sprung into existence with the development of hydro-electric power, although they are based upon principles which were discovered years ago. The metal sodium, for example, is made commercially by practically the same process as was employed by Sir Humphrey Davy when he first began experimenting with the galvanic battery for the reduction of metals. The alternating current that has been adopted in the machines that generate this electricity is the alternating current as studied by Michael Faraday. The change in the potential from 2,200 volts at the machine to 11,000 volts in transmission is effected by the transformers that were discovered by Faraday, and were formerly used chiefly in Ruhmkorff coils and other philosophical instruments. The principle as known then became useful for lighting purposes when the alternating current took its place in the lighting of cities.

In the problem presented at Niagara Falls we had to provide for direct current to operate railroads and for electro-metallurgical purposes. This power is developed as alternating current, and transformed from 2-phase into 3-

phase by an invention of Mr. C. F. Scott, of the Westinghouse Company.

It is a noteworthy fact that, since the first wheels were started in 1895, there have been no stoppages of more than an hour or two at the most. The plant has been in operation night and day, carrying on processes that permit of no interruption on account of the loss which would result.

I regret that I cannot discuss this subject at greater length, for the machinery and appliances installed at Niagara Falls, as well as the industries which have resulted from the development, have made the enterprise one of the important achievements of the period we have under consideration.

Reviewing the century's progress, one cannot but be impressed with the tendency to specialize all industries. It has been truly said that jobbing shops are and always will be a necessity, but that manufacturing establishments will lead in the march of improvement. Trades are becoming more diversified, and time, talent and capital are being expended upon individual machines and appliances as special which were formerly but a part of the output of single establishments. To this concentration of the best thought upon special branches of all industries we may attribute much of the progress in the mechanic arts made during the past seventy-five years, which has opened the markets of the world to the products of our industry. The influence of the Franklin Institute has played no small part in this progress, and as one long identified with its work, I extend my greeting to its members, hoping they will continue to advance the usefulness of an institution which worthily bears the name of one of the greatest philosophers that America, and the world, has produced.

Stated Meeting, held Thursday, November 9, 1899.

THE PRESSING OF STEEL; WITH ESPECIAL REFERENCE TO ECONOMY IN TRANSPORTATION.

BY HENRIK V. LOSS, M.E.

(*Concluded from vol. cxlviii, p. 473.*)

THE THIRD SYSTEM.

When considering the system of closed dies, these latter can be divided into three divisions or methods of application, namely:

(1) All dies to be fixed and stationary, having only the upsetting plunger movable.

(2) The surrounding dies to be partly movable and partly stationary.

(3) The surrounding dies to be all movable.

In the early history of upsetting materials, the first method was the one generally used, and it has been quite commonly adopted even up till to-day. Its great trouble lies in the fact that the necessary power to accomplish a certain work is very excessive, with a correspondingly heavy wear and tear of the dies. This necessary power is especially demanded at the end of the stroke when the dies are to be filled at some point farthermost away from the upsetting plunger. When upsetting rounds on square or round bars, it is a well-known fact that the power necessary to form a good neck is very great. In all upsetting it is a law that the material will flow *near the moving parts*, which, with this method, means near the moving plunger, and the further any stationary part is away from this moving plunger, the slower is the material to flow at this point; and the more power does it naturally take to fill the dies at this remote place. If, during the upsetting of a bar by this method, the latter is taken out of the die with the stroke half done, it will be seen that the metal is heavily upset near the plunger, but also that very little work has been done at the neck. Hence, a system of dies based upon this first division requires a maximum amount of power to accomplish a given work. (See *Fig. 8.*)

There is one application of this method which is in general use to-day—to be sure with some additional modified requirements—and represents a case where any other system would appear to be impossible, namely, the operation of riveting. The stationary dies are represented by the plates to be joined together, but the rivet hole must be filled up. An additional requirement lies in the demand for a well-filled good rivet head; but the hardest work is, after all, to fill the hole.

Fig. 9 represents indicator cards of $\frac{3}{4}$- and $\frac{7}{8}$-inch rivets. As clearly seen, hardly any work is done during the early part of the stroke, while at the finish the pressure rises very fast. The cards were taken on bridge work, and the results in figures, as given below, represent the necessary powers for

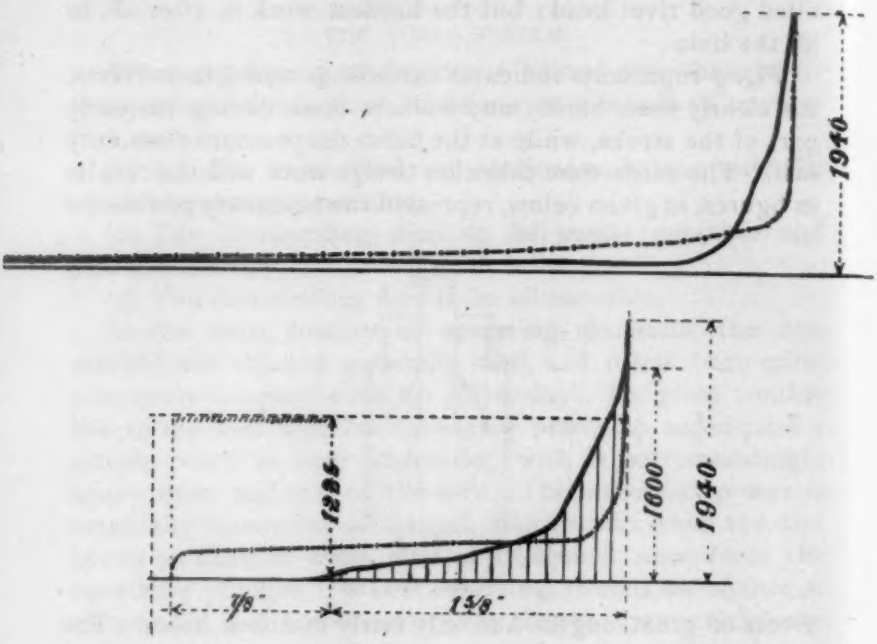
FIG. 8.

rivets of great lengths and only fairly matches holes. The total thickness of plates corresponding to the above cards was $1\frac{1}{2}$ inches or more. It is the sliding of the material against the more or less rough surfaces far away from the die holder which requires the great power used in bridge riveting, as compared to boiler work. The average results from a series of cards were as follows:

The power necessary to complete the heads on $\frac{3}{4}$-inch and $\frac{7}{8}$-inch rivets is about 60 to 70 tons, when working on such grips as mentioned above.

The necessary energy in foot-pounds for $\frac{3}{4}$-inch rivets is 7,200, and for a $\frac{7}{8}$-inch rivet, 9,500, or as in the proportion to the squares of the diameters.

With the view of showing the vastly improved results which can be obtained with short rivets and well-reamed holes, I shall attach some data derived by Mr. Vauclain, superintendent of the Baldwin Locomotive Works, on boiler plates. They form part of a discussion delivered before the Engineers' Club of Philadelphia a few years ago, and are as follows:



⅞-inch rivet.
2⅜-inch material.
67 tons on rivet.
58 per cent. impact.
Acc., 1225.
2½-inch stroke.
22 per cent. efficiency.

FIG. 9.

The suitable pressures for well-fitted boiler work are: For ⅝-inch rivets, 25 tons; for ¾-inch, 33 tons; for ⅞-inch, 50 tons; for 1-inch, 66 tons; for 1⅛-inch, 75 tons; and for 1¼-inch, 100 tons.

Some experiments were made by the William Sellers Company, Inc., on the question of cold riveting, and the results were in part laid before the Engineers' Club of Phila-

delphia, through some notes presented to that body on November 18, 1894, by Mr. Wilfred Lewis. He estimates about 300,000 pounds per square inch of rivet section as being necessary to upset the rivet and form the head.

It is undoubtedly true that the last pressure is concentrated upon the rivet head, and that, hence, the diameter of head enters to some extent when having to decide the total amount of power necessary to drive a rivet. But as the standard of rivet heads does not vary very much between the different makers, it is thus possible to use the rivet diameters as a basis of computation. Again, the resistance existing along the circumference of the rivet hole, when filled, will certainly be transmitted through the body of the rivet back to the tool holder, independent of that part of the head which is outside of the rivet and forms the collar.

A summing up of this division means an early flow with comparatively small stresses, all concentrated near the moving plunger, this to be followed by rapidly-increasing resistances towards the end of the stroke, accompanied by a slow flow at the remote parts.

The next step represents the resistance to flow in dies which are partly movable and partly stationary. When entering upon the question of movable dies an entirely new feature is brought into play, namely, the upsetting or dragging tendency of the surfaces of the movable parts, outside of the plunger itself. The effect of this is naturally beneficial, especially so if the moving dies extend far towards the stationary neck, causing thus, at this remote point, a flow which means directly that much power saved (as compared to the absolutely stationary method) when the final squeeze or pinch is required. The methods of movable or partly movable dies can be applied to almost any form of upsetting, and the principles involved hold good for all; but, as a means of illustration, I shall simply show the results as derived in the upsetting of eye-bars for bridges. The neck dies are, of course, always stationary, the semicircular plunger being always movable, while the remaining top or bottom dies will vary according to the system applied. If they were stationary, the criticism of the first system has

shown the necessary power to be excessive, and the present practice discarded them long ago; but if they are arranged to be stationary on bottom and movable on top, the flow of metal can be best illustrated by *Fig. 10*, which shows the form of a bar half upset and removed from the machine. The plunger has upset the back part, while the moving top die has dragged the metal along and upset the neck. An indicator card showing the power necessary for this division is seen on *Fig. 11*.

More work is here done during the early process of the stroke as compared to what existed with the absolutely stationary dies, but even so the final maximum ordinates are very great in proportion to the earlier dimensions.

The summing up of this division means a more uniform flow throughout the stroke, followed by a tendency towards a more even distribution of pressures.

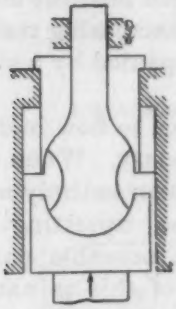


FIG. 10.

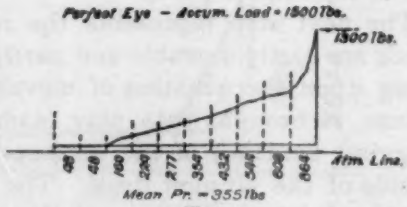


FIG. 11.

The third and last division, having all movable dies, represents an improvement upon the former two, inasmuch as the dragging tendency of the surrounding dies is here brought into play to the greatest possible extent. Hence the distribution of flow and pressures during any one stroke is more uniform than with the former methods. Again, let a bridge eye-bar illustrate this assertion. *Fig. 12* shows a bar partly upset, and the striking feature of *this sketch is the fact that the most remote parts from the plunger or header are the very first parts to upset.* An indicator card of this division is represented by *Fig. 13*, which also shows the great amount of work done during the early stages as compared to the two former methods.

Of course an allowance must be made in all upsetting cards for the extra amount of power necessary to form sharp edges—a power which always manifests itself at the end of the stroke, and which therefore gives somewhat of a false idea as to the general average resistance offered to the flow of the metal during the process.

This third division represents undoubtedly the ideal manner of upsetting materials, and while it has hitherto been applied only to a limited extent, I think such has been due entirely to a want of knowledge of the general flow of metals. The very fact that a result can be obtained by this construction with very much less power than by any other method—and also that offsets, far away from the upsetting plunger, can be filled with a degree of sharpness obtainable

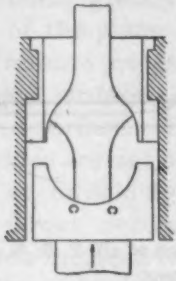


FIG. 12.

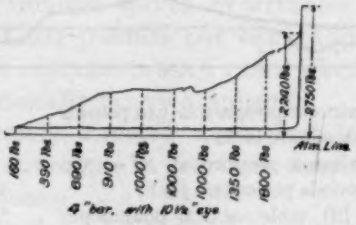


FIG. 13.

with no other system—ought to be enough to ensure its application.

One more important branch of this third system is represented by the process of flanging. The great majority of work of this kind, if heavy, is preferably done under the hydraulic press instead of under the hammer, and the application of flanged work is daily becoming more and more general, superseding riveted or cast sections wherever at all possible. The general work can be divided into two classes, namely, hot and cold flanging.

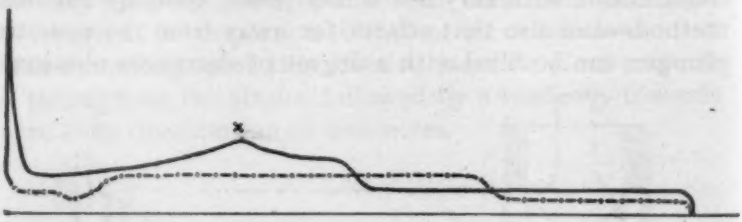
Cold flanging is generally confined to the thinner sizes, $\frac{5}{16}$ inch or $\frac{3}{8}$ inch being the greatest dimensions usually considered safe to be so treated. In all flanging the greatest effort is to edge the plate, that is, to sharpen the corners or bends and take out wrinkles.

Fig. 14 shows a typical indicator diagram of the flanging of the center part, about 17 feet in length, of a sill for a steel car. The material was $\frac{5}{16}$ inch in thickness, and the body of the sill was channel-shaped, having a flange at top and bottom.

A number of cards have been taken from cold work, and the average results can be summed up as follows:

Pressure per running inch to flange $\frac{1}{4}$ inch thick 70,000 pounds steel, 600 to 740 pounds.

Pressure per running inch to flange $\frac{5}{16}$ inch thick 70,000 pounds steel, 710 to 750 pounds.



Maximum pressure = 940 pounds per square inch.
Maximum pressure at × = 330 pounds per square inch.
To lift table = 120 pounds per square inch.
Maximum back pressure = 190 pounds per square inch.
Minimum back pressure = 90 pounds per square inch.

Cross-section of sill P. R. R. car—17 feet long.
$\frac{5}{16}$ inch thick. Two 3⅞-inch flanges.

Scale: 1 inch = 752 pounds.

FIG. 14.—Cold work.

Pressure to edge $\frac{1}{4}$ and $\frac{5}{16}$ inch thick 70,000 pounds steel, 2,500 to 5,800 pounds per running inch.

Whatever variation exists in doing the actual flanging is no doubt due to the variation in the steel, as the material upon which the experiments were made was allowed some latitude both physically and chemically. As to the variation in edging, however, this is mainly due to the difference in radius of curves and general shape of work.

When flanging hot materials it is difficult, if not impossible, to determine the exact pressure per running inch to do the work, because invariably a certain amount of

stretch accompanies the process. In fact, in many instances the necessity for doing so determines, in spite of any thickness, the question as to whether the material shall be treated hot or cold. With hot work, wrinkling or waving is also a strong factor which has to be considered. A number of experiments were made on some ¼-, 7/16- and ½-inch plates, all heated to a bright red, and the resulting figures were as follows:

Pressure necessary to bend the plate and commence the actual flanging varies from 185 pounds per running inch for ¼-inch material up to 380 pounds for ½-inch.

Pressure necessary to complete the flange and sharpen corners varies from 2,100 pounds per running inch for ¼-inch material up to 2,700 pounds for the larger thicknesses, depending greatly, as a matter of course, upon the temperature of the plate.

Pressure necessary to remove waves or wrinkles on a flanged surface = about 1,400 pounds per square inch of waved surface. The latter represents such cases where the wrinkles are not of exceptionally heavy amplitude.

The middle figures, namely, 2,100 to 2,700, contain also the power necessary to overcome a certain amount of stretch incident to the process.

The energy consumed in flanging ¼- and ⅜-inch hot steel plates was found as follows:

For ¼-inch material, 100 foot-pounds per running inch or 400 foot-pounds per square inch.

For ⅜-inch plates, 360 foot-pounds per running inch or 965 foot-pounds per square inch.

Summing up the general features of the third system, we find the resistances to flow as being very gradual in their increase—commencing at zero—and following a line of increments which, toward the final end of its stroke, rises more or less rapidly, depending upon the amount of movable surfaces enclosing the materials to be treated. The metal flows exclusively in the line of pressure, only changing its direction when the motion becomes impeded by meeting a stationary surface, more or less perpendicular to the line of flow.

This constitutes about the limit to the field upon which the speaker has experimented. There are unquestionably some other directions into which the flow of metal enters and which are of importance to the engineer; as, for instance, the reduction of metal when compressed between a pair of revolving rolls; but, I think, nevertheless, that the different processes mentioned in this paper will cover most of the branches of the mechanic arts in which the designing engineer is interested when pursuing his profession.

A number of years ago when, in the line of my duties, it came that I had to design some shearing machinery, I naturally looked around for figures regarding the power necessary to sever metals; and this was my first effort in examining existing published results. My examination covered the publications of different nations as well as of different authors. It was, however, all in vain. What little data the scientific literature did reveal was of a crude character, and did not possess accuracy or logical reasons for its deductions. I then commenced to experiment myself; and little by little my field was increased, until it covered all the topics which I have given you this evening. An entire night could undoubtedly and advantageously be given to each subject, but I thought when covering the field as a whole, it would be easier to see and appreciate the similarities or the differences existing between each particular flow and a better understanding reached than if the subject were split up into details.

If the information given above proves of any advantage to the engineering profession at large, I shall more than consider myself repaid for all the work and trouble involved in carrying out the investigations; and I believe, gentlemen, that the truest and best engineer is after all the one who will combine sufficient ethics with his profession, so as to make him feel that, independent of his obligations to himself and his immediate surroundings, he also owes a debt to the science which has stood by him and enabled him to secure a reputation and livelihood.

Discussion.

Mr. James Christie:—It has hitherto been the usual practice to consider that the resistance to punching per unit of section cut exceeded that of ordinary shearing. This seems reasonable when we consider that the tendency to flow in either case is less restricted in shearing than in punching; in the latter case the act of detrusion is resisted by the clinging of the surrounding mass of metal. Furthermore, the breaking moment which Mr. Loss describes as occurring in the act of shearing, and which operates through a leverage equal to the distance between centers of upper and lower knife, would facilitate the process of shearing; and it does not occur in the same sense in punching. It is, therefore, a matter of surprise when Mr. Loss informs us that his experiments indicate a lower maximum intensity of pressure required per unit of section for punching than for shearing. As the experiments have been numerous, and evidently conducted with care and forethought, we cannot challenge their accuracy without presenting some experimental data in contradiction. This the writer is unable to offer at present. It is to be hoped that Mr. Loss will continue, and will publish further work on the lines embodied in his paper.

Mr. Wilfred Lewis:—This paper treats of a subject of great interest, upon which comparatively little information can be found in print, and the Mechanical and Engineering Section of the Institute is, I think, to be congratulated upon the outcome of this, its first venture, in printing advance copies of its proceedings. The object, of course, is to bring out well-considered discussion, and as Mr. Loss suggests, it should be a pleasure for engineers to repay their indebtedness to the profession which sustains them, not by hoarding the information they have gained by hard study and experience, but by imparting it freely to others. In other words, let there be a liberal interchange of engineering data for the greatest good of the greatest number. Mr. Loss has given us a very comprehensive paper on the Pressing of Steel, and he has covered at one time three divisions of his work on the flow of metals, each

of which might well be made the subject of a separate paper. It is, therefore, to be hoped that we shall hear further from him and that the present paper will be followed by others setting forth more in detail the work upon which he has been engaged.

In my own experience, there have been several occasions when the information contained in this paper would have supplied the data for which a search was made in vain, and as a result William Sellers & Co. were obliged to do as Mr. Loss has done—make their own experiments and deduce their own conclusions. As a representative of this company, I therefore take pleasure in laying before the Section a few notes which I have gathered bearing upon the flow of metals. If they do not accord in every way with the experiments recorded by Mr. Loss, it will be interesting to point out the discrepancies, and their explanation may afford some further light upon the subject.

It is no doubt true that shearing is seldom, if ever, experienced without more or less bending combined, and as Mr. Loss suggests, the transverse stress due to bending may be the real cause of rupture in shearing. This depends somewhat upon the manner in which the work is held, and, in this connection, it is of interest to recall an experiment made about seventeen years ago on a piece of wrought iron $1\frac{1}{2}$ inches thick, as shown in *Fig. 1*. The bar was laid horizontally between the blades of a shearing machine, and, as the blades closed upon it, the bar was left free to assume a natural position during the process of shearing. When rupture occurred, the blades were imbedded upon a surface $\frac{7}{16}$ inch wide, and the bar had rotated through an angle of 20°. Assuming that the pressure over the imbedded surfaces was pretty evenly distributed as the result of flow in the metal, and that the top rake on the shear blades was about at the angle of friction, the bending stress can be shown in this case to have been about equal in intensity to the shearing stress. The principal stresses due to these bending and shearing stresses will be one of tension of about $\frac{5}{3}$ the intensity of shearing and one in compression of $\frac{2}{3}$ the shearing intensity. Therefore

rupture by cross-breaking should occur when the shearing stress reaches $\frac{3}{5}$ of the ultimate tensile strength. Although there may be some inaccuracies in the assumptions made, it will be seen that this observation upon the indentation of shear blades corroborates Mr. Loss' conclusion that shearing is really cross-breaking and that the intensity of shearing resistance is about $\frac{3}{5}$ the ultimate tensile strength. If the sheared section could be relieved of bending stress, its resistance would naturally be increased, and it is, therefore, surprising to find the resistance to punching given as

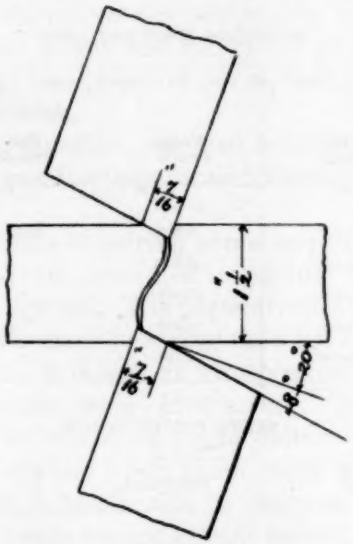


FIG. 1.

less than that of straight shearing. In punching, there is also some bending stress in the body of the metal punched out, but very little, if any, on the line of shear.

Possibly the figures given by Mr. Loss refer to bevelled punches, but if they refer to flat, they differ widely from the results obtained in my own experience.

The experiments bearing on this were made to determine the relative merits of flat and bevelled punches in material of different thicknesses. The punches were all $\frac{3}{4}$ inch diameter, with dies $\frac{1}{8}$ inch larger, and the material

ranged from $\frac{1}{4}$ inch to $\frac{3}{4}$ inch thick. One punch was flat, another V-shaped, the sides of which inclined 120°, and a third had an end in the form of a double spiral.

The punches and dies were set as usual in a punching machine, but the eccentric shaft was disconnected and the machine was turned on one side to bring the slide against the ram of a hydraulic wheel press. A pressure gauge on the cylinder indicated the working pressures per square inch from which the total pressures were estimated, and these divided by the surface cut through gave the following pressures per square inch in punching:

PUNCHING WROUGHT IRON.

Thickness of Metal.	Flat Punch.	Wedge Punch.	Hard Steel.	
			Flat Punch.	Wedge Punch.
Inch.				
¼	43,100	16,100	80,000	48,000
⅜	49,100	39,800	—	—
½	49,400	41,100	—	—
⅝	52,000	50,000	—	—
¾	48,500	52,100	—	—

STEEL BOILER PLATE.

Thickness of Metal.	Flat Punch.	Wedge Punch.
Inch.		
⅜	49,100	39,800
½	49,400	49,400
⅝	52,000	58,200

The spiral punch did no better than the wedge punch and was soon damaged beyond further usefulness.

Care was taken to obtain a reliable gauge in making these tests, but, before accepting any disputed values, a repetition of the experiments in a different way, as, for example, between the heads of a testing machine, would seem desirable. It appears from these experiments, however,

that the shearing resistance in punching approximates very closely to the ultimate tensile strength of the material. On thin material the wedge punch naturally takes less pressure, but as the thickness approaches the diameter of the punch the value of the wedge lessens and finally disappears. On thin material also the flat punch requires less pressure per square inch of sheared surface, the cause of which may be looked for in the greater effect of the die clearance. When the metal is thin, the line of cleavage is more inclined than when it is thick, and a greater proportion of cross bending stress is thrown upon the sheared surface. It is therefore not surprising that, with $\frac{1}{8}$ inch clearance between punch and die, metal $\frac{1}{4}$ inch thick should require decidedly less pressure per square inch than metal $\frac{5}{8}$ inch or $\frac{3}{4}$ inch thick.

The question, therefore, remains whether punching pressures are really greater than those for straight shearing, and if so, why?

Another anomaly requiring some explanation is the energy per square inch consumed in cutting rectangular steel bars, given on page 468. It is perfectly clear that flat knives require more pressure in shearing than knives set at an angle to each other, but it is not at all apparent why the latter should consume less energy in shearing. Indeed, when it is considered that knives at an angle distort the piece cut off and have thus imposed upon them more work than that of shearing alone, it is reasonable to suppose that the energy consumed with angle blades should exceed that with parallel flat knives.

Again, on the same page the expression for the pressure required to shear angle iron makes this pressure depend upon the square root of the thickness of the metal, whereas, a little further down, the pressure required to shear flat bars is made to vary directly with the thickness. There is an apparent inconsistency in these expressions which makes it difficult to believe both.

The energy consumed in shearing is, I think, properly expressed in terms of the thickness squared, as given on the same page, and from this it can be argued that the shearing

pressure must vary directly as the thickness and not as the square root thereof. By analogy from shearing to punching, the energy consumed in punching should also vary with the thickness squared, and, as far as my experience goes, this is really the case, but I have no data on very deep punching where the metal removed is decidedly less in volume than the hole produced. But there are no examples of the latter kind of punching given in the paper, and yet on pages 471 and 472 the energy consumed is expressed in terms of the area of the hole without reference to the thickness punched through. It would therefore seem desirable to recast the values there given to accord in form with the expression given on page 468 for the energy consumed in shearing angles, where the thickness squared very properly appears.

In regard to riveting pressures it is shown pretty clearly in this example of cold riveting that excessive pressure will actually stretch the metal around the rivet and to a very marked extent when more than 300,000 pounds per square inch of rivet section is applied.

Our experiments on hot shearing and upsetting are too extensive to review in detail this evening. They were made upon a bloom shear at the Midvale Steel Works about fourteen years ago, and cards were taken by an indicator attached to a large steam cylinder, the plunger of which forced water into another large cylinder which did the work. Suffice it to say that as far as comparisons can be made our results agree very well with those given by Mr. Loss.

Physical and Astronomical Section.

INTRODUCTORY ADDRESS.

By Dr. A. E. Kennelly,
President of the Section.

[Commemorative Meeting held in Convention Hall, National Export Exposition, Friday, October 6th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

The Physical and Astronomical Section of the Franklin Institute, brought to your notice this evening, is the youngest section which has been organized by that body, and, in fact, has not yet passed out of its first year of existence. We feel, however, no diffidence on this score, because the sciences which this section is intended to serve have already received the Institute's consideration under less specialized and divided guise. The mechanic arts themselves, for the cultivation of which the Franklin Institute was founded, are but working bees of the hive of Natural Science in general, and of Statics and Dynamics in particular. No man can design the simplest machine without some scientific knowledge, even though he does not know it by that title, and the more complex the machine, the more scientific knowledge he must possess.

Moreover, these sciences are themselves of the most remote human antiquity. Physics, in some form, however limited, must have been studied by man at every era of his existence, and we find that some practically-acquired knowledge of physical principles is even to be found in the lower animals. As for astronomy, or the natural philosophy of the heavenly bodies, it can only be second in antiquity to physics. The constellations look down upon us in much the same aspect that they looked down upon the earliest recorded times of our ancestors, and although they, too, reckon with time and change, yet by comparison with ourselves they stand out to our gaze as emblematic of immutability.

There are two peculiarities of the exact sciences, to the devotion of which this section has been created. One is that they manifest a tendency to speak in the exact language of mathematics, and the other is that difference of opinion tends to disappear upon the subjects which they adopt. Upon practically every subject which is not included in the exact sciences, except recorded history, there exists, as a rule, a great variety of opinions, and the difference of opinion generally increases with the distance of the subject from the sphere of exact science. On such questions as the Monroe Doctrine, or the comparative beauty of orchids and geraniums, or the probable future of the Chinese Empire, we may expect to find every variety of opinion and judgment. But upon the area of a circle of two feet radius, the shape of the earth, or the distance of the moon, there is practically no difference of opinion, and such difference of opinion as does exist is restricted to such narrow limits of uncertitude or precision as to the uninitiated seems trivial and incongruous. Yet we know from history that there have been times when men disputed vehemently upon all of these questions; that is to say, before the exact sciences were sufficiently powerful to annex them. We find, indeed, vexed questions and disputes in the domains of the exact sciences, but, as a general rule, these are only on matters which have thus far eluded complete measurement and systematic generalization. The law of these questions has not yet been discovered, and for this reason they are still outside the empire of exact science. As time goes on, labor achieves, and knowledge advances, these things become measured and known, whereby dispute terminates and dissension disappears. Whether we should care to live in a world where everything belonged to the exact sciences, and in which the cause and order of all things could be found in the encyclopedia, is, of course, open to debate; but it is beyond dispute that the practical unanimity of educated opinion, upon subjects included in the exact sciences, entitled those sciences to a dignity and importance that is withheld from communities of facts that obey, as yet, no recognized law.

On looking back through the history of past centuries, it is impossible to avoid recognizing the fact that the exact sciences of the remote past had but very little practical application. Astronomers, while devoting their lives unremittingly to the study of the heavenly bodies, and fully impressed with the dignity of their task, cast horoscopes and predicted nativities. Physicists, such as Archimedes, occasionally performed useful services for the community; but many mathematicians, such as Pythagoras, disdained all utilitarian aims as unworthy of their study. To them, knowledge, jealous of the attention of her devotees, frowned at all flirtations with utility.

The necessities of modern civilization, however, have swept away the prejudices that encompassed and secluded scientific research. We could not maintain the fabric of existing institutions without the aid of the applied sciences.

It is very doubtful whether the existing population of cities like London and New York could even be sustained in food, if the applied sciences were in the stage of their development at the beginning of this century, before the locomotive steam engine made its appearance. Even if the necessaries of life could be carried in to the cities from the surrounding country, in sufficient quantities, by horse wagons, the cost of transportation would make city life economically impossible to a large section of the community. Without the machinery which is the outcome of applied science, our clothing, shelter and food would require all the average man's time and effort to secure for his family and himself, and luxuries would become impossibilities. The federal government of such a large area as the United States would become a practical impossibility under the same circumstances. It is recorded that in 1812, before the days of the electric telegraph, the Government at Washington did not receive the news of the battle of New Orleans until more than three weeks after the event.

The absolute dependence of modern civilized society upon the work of the applied sciences is so great that these sciences are taxed to their utmost limit. More and better machinery is needed, cheaper, simpler and more effective than

existing machinery. Competition among machines is to-day keener than the competition among men, because even the most systematic men are subject to some erratic or variable impulses which reduce the closeness and keenness of their mutual competition; whereas, machines, while maintained in repair, work with a zeal that knows no weariness and a regularity that no emotions can disturb. The result is that all the engineering sciences and applied sciences generally are taxed to their utmost to supply the needs of society. These applied sciences turn eagerly to the exact sciences for fresh material to place at the public hand. In former years there was so little demand for the applied sciences that the pure sciences only gave their rejected surplus to applications. Now the demand is so great that a large amount of purely scientific work is done in the world each year, in the hope that some of the results can be made available for utilitarian purposes. The study of the steam engine for the purpose of cheapening and improving it has added enormously to the world's scientific knowledge concerning the laws of thermodynamics. The first endeavors to lay the Atlantic telegraph cable added in a great measure to scientific knowledge concerning the ocean and its doings. The study of guns for use in war has contributed largely to the stock of accurate information concerning the motion of projectiles in resisting media. Conversely, it is almost impossible to discover any new scientific fact without finding a useful purpose for it to fill. Röntgen, for example, had scarcely more than announced the discovery of his new invisible rays, when surgeons began to use them. After looking back upon the past, it is impossible to look forward without being convinced that the practical man of the future will be more of a scientist than ever. Current literature, current speech and current development all make this confession of faith. In the days that are now behind us, an inventor who had only acquired a very moderate amount of applied science, by untrained observation and experience, could, by native ingenuity, introduce great improvements in the relatively crude industrial processes of his time. In the days that are before us, however, industrial processes

are becoming so specialized, so complex and so linked with mechanical processes, that an inventor must be possessed of either greater natural ability to improve the result, or must have received some scientific training. In fact, whereas it was at one time true that "necessity was the mother of invention," it is now more nearly correct to say that science and necessity are the parents of invention. Natural science is in the last analysis, only the study of natural phenomena and of their laws, and the more complex the machinery by which those laws are controlled for industrial purposes, the more intimate must be our knowledge of them.

The benefits which have been derived during the past seventy-five years—the lifetime of the Franklin Institute—from the progress of the exact sciences and their industrial applications have been numerous. They have so modified nearly every industry as practically to revolutionize it. Where, perhaps, one hundred men then labored with weary arms, one or two men now accomplish the same result with the aid of machines. The result of all this has been that the total production of communities, per worker, has been enormously increased, so that although the average hours of labor have somewhat decreased, the average purchase of a day's labor in money has increased appreciably, and its purchase in commodities has increased very markedly. The application of the exact sciences to the forces of life has made and must continue to make life easier, brighter and more comfortable to the average member of the community.

The exact sciences pour more than pure wealth into the lap of the nation that applies them. They also ennoble. Ignorant man, the man of very limited science, is swathed in superstition; he sees a particular spirit in every natural phenomenon and a demon in every adverse circumstance. Gradually, as he learns the laws of his environment, his superstition melts away, more intimate appreciation of the nature of the universe raises him mentally and morally, while the greater control he obtains over the processes of nature, the higher the elevation to which he rises. The average man of the community to-day possesses much more

scientific knowledge than did the average man of past centuries. The average man of the community to-day is better, brighter and more comfortable, for his knowledge as well as for his power. Acquaintance with the laws of the universe, which cannot falsify, unconsciously teaches truth to all those who learn them, while the capability of being able to transport material from New York to Chicago in twenty-four hours, and the ability to converse over the same distance by telephone, is a partial apotheosis of the entire race in which the ability resides. Every new achievement of this kind which science brings within our grasp, elevates humanity to a higher and nobler plane, and every earnest worker necessarily contributes to the elevation of his race.

It is, then, to the applied sciences of the future that we must look for the advances that are to make the world happier and greater than it is to-day. The result must come if no cataclysm intervene; for the forces of civilization, once given headway, are self-supporting and inevitable in their tendency. The applied sciences in their turn look to the exact sciences for development and support. The fostering and development of scientific training, knowledge, skill and application, is of vast importance to the community at the present time. That country and race and language must predominate in the world by which the natural sciences are most abundantly applied. There are no public institutions, except the hospital for the care of the sick, and the school for the education of the young, which are of more importance to the community than institutions which, like the Franklin Institute, cultivate the knowledge and application of the natural sciences.

SOME NOTABLE CONTRIBUTIONS OF AMERICAN PHYSICISTS DURING THE LAST THREE-QUARTERS OF A CENTURY.

By T. C. MENDENHALL,
Honorary member of the Institute, President of the Worcester Polytechnic Institute, Worcester, Mass.

[An address delivered in Convention Hall, National Export Exposition, Friday, October 6th, at the Commemorative Meeting of the Chemical Section, on the Occasion of the Seventy-fifth Anniversary Exercises of the Franklin Institute.]

The cheerfully optimistic spirit which, fortunately, prevails everywhere and always among the masses of the people, easily and naturally leads to the conclusion that the present age is the golden age. Of all times in the history of the world, NOW is the most important. Never so much wisdom as now; never so much wit and courage and beauty as now; never so many things that make life worth living as now. So it was one hundred and two hundred years ago and so it will be one hundred and two hundred years hence, for the delightful disposition to accept things as they are, and not only to accept but to approve and admire, is a large and important element in that wonderful resilience which enables the human race to smile at discouragement and defy disaster. Moreover, it is a logical acceptance of evolution; an unconscious recognition of a development from worse to better, on the whole, steady and persistent.

But when one makes even a superficial examination of the centuries that have preceded our own, notwithstanding the meager knowledge we possess of some of them, it is immediately evident that such a view of existing conditions has not always been sound. It is at once seen that the progress of the race has not always been steady; that it has sometimes and for considerable periods inclined towards the worse, rather than the better, and that certain centuries stand in marked contrast with others when measure is taken of the intellectual growth and material development by

which mankind has been most profoundly affected. It is this fact which gives one whose life has been wholly in the nineteenth century courage to declare that the cycle of years now coming to an end is enormously more significant in its determination of the relation of men to each other and to the universe in which they live, than any that have gone before. Indeed, it is but conservatism to declare that the nineteenth century, along certain lines of development, especially those relating to the physical condition of man, must be credited with achievements beyond those of all past time. Argument in support of this proposition has become almost commonplace, and a brief reference to a few of the more striking illustrations will be sufficient, as it may also be necessary, to create a just appreciation of some contributions to this splendid evolution which will presently be considered.

One of the most notable transformations wrought during the century is found in improved locomotion, including the transfer of goods. We do not know who invented the wheeled vehicle. It was probably in use in prehistoric times. Nor do we know who first tamed the beasts, thus substituting the muscular energy of animals for that of men. But we do know that from that remote period to the end of the first quarter of the nineteenth century, nothing essentially *new* in the way of locomotion on land was invented. The coach in which George Washington rode differed only in details of construction from that chariot into which Joseph stepped, "arrayed in vestures of fine linen," and its motive power was the same. We do not know who first spread a sail to catch the power of the wind for propelling a boat, but we do know that, previous to the nineteenth century, no ship was ever driven otherwise. It is doubtful if the speed of travelling on land and sea was materially greater in 1799 than a thousand years earlier, although improved roadways and larger vessels lessened the cost per ton mile of freight. How startling is the contrast of these methods of locomotion, the total result of thirty or forty centuries of effort, with the accomplishments of the last three-quarters of the nineteenth century. But far more

amazing is the revolution which has taken place within the same period, in the methods of conveying intelligence from point to point. The telegraph and telephone could hardly have been conceived by even the most imaginative of those whose day preceded ours, and their influence upon the social and material conditions of men is yet far from its maximum. One of the most pregnant discoveries of all time was the art of controlling fire. The use of flint and steel for its production, which comes to us from the remote past, was still general during the first quarter of the century and many people are now living who were accustomed in their youth to "borrow" fire from their neighbors, in the absence of any means of creating it. The artificial light of the early part of the century was produced by methods not essentially different from those in use for thousands of years, the first real advance being the improved draught of the Argand burner. The clothing worn by our revolutionary forefathers was generally woven on hand looms and the parts were stitched together by hand, the whole process of production not differing materially from that of the "coat of many colors." During the earlier years of the present century, the harvest was gathered just as it was in the days of Ruth, and the several processes by which grain was converted into bread had altered little in thousands of years.

All of these are matters with which everybody is concerned, for food, clothing, fire, light and the means of bringing supply and demand together may be said to constitute the minimum requirements of human existence. In all of them the marvellous work of the nineteenth century overshadows that of all that have gone before.

One of the most important and suggestive books of recent publication is entitled "The Wonderful Century," by Mr. Alfred Russell Wallace, the distinguished English naturalist, who shares with Darwin the honor of conceiving one of the two most notable generalizations of modern science. In this work Mr. Wallace attempts an estimate of the value of the achievements of the nineteenth century as compared with those of all the centuries that have preceded it. In his summary he includes great inventions

and discoveries in both pure or theoretical and applied science. In all he enumerates thirty-nine, of which twenty-four are to be credited to the present century and fifteen to all previous time. While in the specific selection of these epoch-making events there is much room for difference of opinion, there cannot fail to be a general agreement as to the net result. The nineteenth is truly the "wonderful century," and whatever the twentieth or the twenty-first or the twenty-second may bring forth, this verdict is not likely to be reversed.

In reviewing the achievements of this century it is found, further, that by far the largest part of this industrial and social revolution has been enacted during the past seventy-five years, that is, during the life of the Franklin Institute, the seventy-fifth anniversary of the founding of which is now being celebrated. That it may justly exhibit pride in its long and illustrious career no one will deny, for its activity during this memorable period has contributed in no small degree to the large share which our country has had in the making of modern civilization.

My own duty on this most interesting occasion, as assigned to me by the Committee of Arrangements, is the presentation of a sketch of the progress of the science of physics during the period covered by the life of the Institute. The difficulty of the task which I have undertaken will be appreciated when I remind you of the fact that it is to discoveries in physical science and their application in invention and construction, that we owe by far the larger share of what goes to make this period unique in history. Indeed, it would be a task utterly impossible in the time to which I must restrict myself if I were to attempt anything like a general treatment of the subject. Even a limitation to a review of the contributions of American physicists to the progress of the science during this period would still constitute a performance impossible under reasonable conditions. I am compelled, therefore, to confine myself to what will be the merest outline of the work of a comparatively small number of those eminent men, living and dead, who have conferred honor upon their country by their splendid

contributions to physical science. I ask your indulgence and sympathy in attempting what cannot fail to be an utterly inadequate survey of a large field, and I wish especially to emphasize the fact that I make no pretense of thoroughness or of even enumerating all of those who would be justly entitled to mention in any other than a hasty sketch.

Natural science in the nineteenth century may boast of two great generalizations, of the conception and proof of two great laws or fundamental principles, against which the past might put the establishment of the Copernican theory of the solar system and the discovery and proof of the law of universal gravitation. One of them has been proved by observation, the other by experiment. The latter is the principle of the Conservation of Energy, which has been found an unerring guide in physical research. With the early history of this principle a countryman of ours had much to do. To an American, yet not an American, Count Rumford, is generally given the credit of being the first to fully realize and to distinctly announce the true character of heat as a form of energy. Driven from his home in New England by the cruel and now believed to be absolutely unfounded suspicions of his neighbors, he left his country only to return as her enemy, and while we have for a century profited by his subsequent generosity, we cannot fairly put his brilliant career as a scientific man to the credit side of our account. Barring Rumford's share in the principle of the Conservation of Energy, which is everywhere admitted to be large, it cannot be claimed that American physicists contributed largely to its establishment, at least not directly.

But in that domain of physical science comprehended by the term Radiant Energy, the contributions of American scholars during the past seventy-five years have been of first rank. Among the earliest workers in this field, and in many respects the most eminent, was Dr. John William Draper, and it is an interesting fact that his first scientific papers were published in the *Journal of the Franklin Institute.* Although an Englishman by birth, Draper was a

loyal American from the time he took up his residence in this country at the age of 21 years. While an undergraduate in the Medical College of the University of Pennsylvania he began to display remarkable talent for original research, and his first paper "On the Nature of Capillary Attraction" was published in the *Journal* of the Institute in 1834. In 1835, before receiving his degree, he published in the same journal his first paper on light, being an account of experiments to determine whether or not it exhibited any magnetic properties. During his long life of threescore and ten years he was a most industrious investigator and voluminous writer, but his most important work in pure science had to do with light. In this he anticipated many of the results of later researches, although due credit has not always been given him. He was one of the first to examine the influence of light in producing chemical changes and was among the pioneers in the science and art of photography. The first photographic picture from life was made by him, the face of his sitter, who was his own sister, "being dusted with a white powder." On a bright day a picture was secured in five to seven minutes. He also made the first photograph of the moon. As early as 1834 he had attempted, but without success, to photograph the fixed lines of the solar spectrum, and in 1837 he began a notable series of researches on the nature of rays of light in the spectrum, and with the splendid discovery of spectrum analysis his name must always be associated. In the course of this investigation he anticipated several of the fundamental discoveries of Kirchhoff, made public by him in a celebrated memoir thirteen years later than that of Draper. His paper, "On the Production of Light by Heat," was printed in the *Philosophical Magazine* for May, 1847, and in it he declared that he had established, experimentally, the following important facts:

All solids and probably all liquids become incandescent at the same temperature.

The rays emitted by solids from common temperatures up to nearly 979° F. are invisible; at that temperature they are red, and the heat of the incandescing body being made

continuously to increase, other rays are added, increasing in refragibility as the temperature rises.

Whilst the addition of rays so much the more refragible as the temperature is higher is taking place, there is an augmentation in the intensity of those already existing.

The spectrum of an incandescent solid is continuous; it contains neither bright nor dark lines.

These proportions are almost identical with those published by Kirchhoff in 1860, and upon which the spectrum analysis is founded. Had Draper made no other contributions to physics, his memoir of 1847 would have entitled him to high rank. But, in addition, he was the first to discover that in the ultra violet part of the solar spectrum there are absorption bands similar to the Fraunhofer lines of the visible spectrum. He studied the chemical effects of the different portions of the spectrum, the distribution of heat in the diffraction spectrum, the action of light on the growth of plants, and made many other researches which cannot even be mentioned here. He suggested, as a standard of photometry for white light, a piece of platinum foil of given area and thickness, heated to incandescence by an electric current of specified strength, thus, in fact, anticipating the incandescent electric lamp of Edison, and in a general way many proposed photometric standards of later date. Dr. Draper's tremendous intellectual activity was displayed in many fields and he is perhaps more widely known as the author of historical and controversial works than as a physicist. His "History of the Intellectual Development of Europe" is quoted with that of Buckle, and his "History of the Conflict Between Religion and Science" has passed through more than a score of editions in English, has been translated into nearly every known tongue, and was honored by a place in the "Index Expurgatorius," along with Galileo, Copernicus and Kepler.

Almost contemporaneous with Draper was Lewis M. Rutherfurd, whose scientific researches were also mostly made in the city of New York. Mr. Rutherfurd devoted much time and energy to the development of celestial photography, besides making important contributions to our knowledge of the solar spectrum. He constructed a

spectroscope with six large bisulphide of carbon prisms, using many ingenious devices for overcoming the many difficulties which the making of an instrument of such dimensions involved. Among these was the now well-known arrangement for adjustment of the prism to the position of minimum deviation for rays of different refragibility. The application of the photographic camera to this instrument resulted in a magnificent map of the solar spectrum, especially of that part extending from F to H, which was for a long time unequalled. His experience in the production of this photograph led him to undertake the making of a diffraction grating, with which he believed he could obtain more satisfactory results. The gratings with which the memorable researches of Fraunhofer had been made were of fine wire, varying in diameter from about one-twenty-fifth to about two-thirds of a millimeter. The grating space distances between the center of the adjacent wires ranged from somewhat more than one-twentieth to seven-tenths of a millimeter. With instruments so crude as these, Fraunhofer had measured the wave length of a few of the most prominent spectrum lines with an accuracy which must command our highest admiration, but he had practically exhausted the possibilities of a wire grating. Nobert had devised a method of ruling fine lines upon glass, but his secret was carefully guarded. Although capable of ruling lines very close together, the inequality of spacing which they almost invariably exhibited greatly lessened their value for optical researches. As early as 1863 Rutherfurd attacked this problem and with such success that, as a result of his own efforts, supplemented as they have been by the later work of Rowland, American diffraction gratings have been, and are to-day, incomparably superior to those made elsewhere. In Rutherfurd's first ruling machine the movement of the plate upon which the lines were ruled was accomplished by a system of levers, but a screw was soon substituted for this, on the suggestion of Professor Rood. With the new machine gratings were ruled upon glass and also on spectrum metal, the most perfect examples being of the latter type. As many as 17,000

lines to the inch, the lines being nearly an inch and three-quarters in length, were ruled with a perfected machine and with a uniformity of spacing previously unheard of. Indeed, the diffraction spectrum was seen as it had never been seen before. Physicists were now enabled to make accurate measures of wave length with even faint sources of light, and were thus put in possession of a new instrument of research of great value.

In this connection, mention should be made of Mr. Chapman, Rutherfurd's skilful assistant, who contributed much to the final triumph by his mechanical ingenuity and patient industry. Rutherfurd was a member of the National Academy of Sciences and other scientific societies. He was extremely modest and apparently indifferent to public recognition, and as a result his excellent work has not received that notice, either at home or abroad, to which it is justly entitled.

No account of the contributions of American physicists to our knowledge of spectrum analysis would be complete without mention of important investigations made by Dr. Wolcott Gibbs, now President of the National Academy of Sciences. Although a chemist rather than a physicist, Dr. Gibbs's researches have often led him into the domain of pure physics and his work has always been of the first rank.

Ignoring chronological order, it will be most fitting to refer, at this point, to the admirable investigations in the field of optics by which Rowland has contributed to the renown of American science. The scientific importance of Rutherfurd's improved gratings, and the interesting results growing out of their use, encouraged others to attempt the construction of ruling engines which should be still more perfect, for even Rutherfurd's best plates revealed certain irregularities in the spacing of lines, seriously interfering with their highest usefulness. The interesting problem was to devise a process by which a screw could be cut more uniform in pitch than that of the lathe on which the cutting was done. Professor W. A. Rogers gave much time and ingenuity to the solution of this problem and had

devised a method for correcting the errors of the lathe screw, by moving the cutting tool in a determinate manner. The solution was not entirely satisfactory, however, and when Rowland attacked the problem of making a perfect screw, he practically ignored all attempts to correct or allow for the errors of the lathe guide. Briefly, his solution, which was wonderfully complete, amounts to saying that a screw must first be cut as perfect as possible on the best lathe attainable and then it must be freed from errors by grinding in a long, reversible nut by which all sensible inequalities may be eliminated. Having prepared a screw in this manner, Rowland mounted it in a dividing or ruling engine and began to rule diffraction gratings. Great care was taken to shield the plate and machine from temperature changes or accidental disturbances during the process of ruling, and it is but just to say that the results were far superior to anything that had been previously accomplished. Moreover, Rowland hit upon the happy idea of ruling on a concave reflecting surface, so that the use of lenses might be dispensed with. He has enlarged the dimensions of these gratings and improved their quality to an extent no one had thought possible, and he has devised special forms of apparatus by which they may be used in photographing spectra. He has himself completed a most extensive series of photographic maps of the whole solar spectrum, on a scale enormously greater than any attempted before he made this special field his own. His gratings and photographic methods in the hands of other observers have been the means of adding greatly to our knowledge, not only of the solar spectrum, but of the spectra of the elements, stellar spectra, etc., and it may justly be said that no more important contribution to spectrum analysis has been made anywhere during the past twenty-five years.

In the determination of one of the most important optical constants, the velocity of light, it is universally conceded that American physicists have reached the highest degree of precision. So swift is the speed of light that it was long thought to require no time in travelling from point to point. Galileo thought it must have a finite velocity and made

some experiments to determine if this were true, but without success. In 1676, Römer, a young Danish astronomer, announced to the French Academy of Science his discovery of the velocity of light, by observations of the eclipses of Jupiter's satellites, and this important fact was confirmed not long after by Bradley, the English astronomer, in the discovery of "aberration," which furnished a much more accurate value of the velocity constant than that given by the Dane. For a long time it was not thought possible to measure the velocity of light, exceeding as it does 180,000 miles per second of time, by any other than astronomical methods in which the space travelled over was sufficiently great to require a measurable period of time. In the early part of this century, however, it became very important to devise a means of measuring very small intervals of time with such accuracy as to make it possible to determine the velocity of light travelling over short distances, and the skill of the ablest physicists was challenged to accomplish this result. The difficulty of the problem will be understood when it is remembered that light will travel a mile in a little more than one-two-hundred-thousandth of a second, and if that distance could be used as the base, for the result to be true within 1 per cent. it would be necessary to measure time correctly to within one-twenty-millionth of a second. The importance of the problem grew out of the fact that the emission theory of light, as conceived by Newton, still, up to the middle of this century, had many adherents, and an *experimentum crucis* which would forever determine between that and the wave theory was greatly desired. This presented itself in the relative velocity of light in rare and dense media, in regard to which the two theories were diametrically opposed to each other. Everybody knows how Foucault, taking advantage of an ingenious application of a swiftly-revolving mirror used by Wheatstone, in an attempt to measure the velocity of electricity, completely settled the question by a beautiful experiment which he reported to the French Academy on May 6, 1850. Finding the velocity less in water than in air, the emission theory of light was compelled to yield its last foothold. But there

were many other problems of great interest to be solved by more accurate methods of measuring the velocity of light and many physicists attempted to improve upon Foucault's process. The most successful of all was Michelson, a graduate of the U. S. Naval Academy, who so modified Foucault's apparatus as to insure an accuracy about two hundred times as great. In conjunction with Newcomb, America's most distinguished astronomer, he made a series of experiments which are everywhere accepted as the most refined determinations of this important constant. Michelson has since devoted most of his energy and talent to optical research, in every department of which he has met with signal success. In his invention of the Interferometer he has furnished an instrument for delicate research in light transmission productive of many very important results. In 1892 he succeeded in making a very precise comparison of the wave-length of light with the international prototype meter at Paris, the unit of length for the civilized world, and he has successfully carried out other researches in light too numerous to mention here.

Very important contributions to our knowledge of the solar spectrum have been made by Langley, Secretary of the Smithsonian Institution. They were begun at the Allegheny Observatory, of which he was director, and have been continued, being, indeed, still in progress at the Astro-physical Observatory at Washington. Langley made an important modification of Siemens's electric resistance thermometer, adapting it to the most refined problems of radiant energy, and in his hands the Bolometer, as it is called, has thrown a flood of light upon hitherto unexplored regions of the solar spectrum. He has especially explored the infra-red region of the spectrum and has been able to detect radiation of wave-lengths enormously greater than any hitherto found. He has utilized the same device in an investigation of the temperature of the moon, and in the study of sources of light apparently unaccompanied by heat. One of his most interesting researches has revealed the fact that the char. acter of sunlight is greatly modified by absorption in its passage through the earth's atmosphere, and that the color

of the sun, if it could be seen unaffected by this absorption, would be a greenish-blue.

The restrictions of the occasion will not permit of further details of these interesting investigations or of other important contributions to optics made by American physicists. It is impossible, however, to omit a brief mention of the indebtedness of American students of optics, and of scientific men throughout the world, to the exquisite skill in the production of optical apparatus possessed by two or three American artists. Pre-eminent in this field have been the Clarks, father and sons, now alas! dead, and Brashear, of Allegheny, still in the prime of a life which has been devoted to the mastery of mechanical difficulties in the way of producing optical surfaces of the very highest accuracy. The almost unique position which American physicists occupy to-day in the domain of optical research is largely due to the delicate touch and brain-directed handicraft of these men.

Equally important extensions of our knowledge of that form of radiant energy known as heat have taken place during the last three-quarters of the century, but the contributions of American physicists have not here been so notable. Much has been done, however, worthy of mention, if only time permitted, and some record must be made of work in this field not already included in the investigations of Draper, Langley and others. Rowland's determination of the mechanical equivalent of heat will always rank as a classic. Following the general plan of Joule's famous experiment he greatly improved the apparatus, giving especial attention to the change in the specific heat of water with varying temperature, and the thermometric part of the work was much more precise than that of Joule. The practical value of the result was great, and the theoretical even greater, because it has destroyed certain discrepancies previously existing among values of this constant obtained by widely differing methods.

If I had to do with applied physics, there would be much to say of the share of our countrymen in the wonderful development and improvement of heat-engines and of the

enormously increased utilization of the energy of fuel, but this phase of the question I must not touch.

In that department of physics of which but little was known a hundred years ago—electricity and magnetism—our philosophers have been among the first. At the close of the last century our most brilliant scholar and diplomat, Benjamin Franklin, was the world's most distinguished electrician. When this institution which bears his name was assuming form seventy-five years ago, one who was destined to be second only to him in renown as a student of electricity was just beginning a series of investigations which added great luster to American science. Of the work of Joseph Henry in electricity, most of which was done while he was still a very young man, at the Albany Academy, I may be permitted to quote what I have said in another place. His first important work was the development and perfecting of the electro-magnet. With this now commonplace but most important electrical device three names will always be associated. Shortly after the announcement of Oersted's brilliant discovery, which furnished the first connecting link between electricity and magnetism, Arago had announced the interesting fact that if rods of steel or iron were placed in a glass tube around which a wire was coiled so that the adjacent rings did not touch each other, they would become magnetic on the passage of a current of electricity through the wire. Thus Oersted's discovery, that an electrical current would *influence* a magnet, was supplemented by Arago's, that it would also *produce* a magnet. Three or four years later another notable step in advance was made by Sturgeon, in England, who produced for the first time what has since been known as an "electro-magnet." He bent a bar of soft iron into the shape of a horseshoe, thus bringing the poles into the same plane for greater convenience; and he dispensed with the glass tube used by Arago, by varnishing his iron core, thus insulating the coils of naked wire, which he wound in a spiral about it. But the most powerful electro-magnets made by Sturgeon's method were insignificant compared with what Henry was able to produce a few years later. Instead of varnishing

the iron core and using naked wire, he insulated the copper wire itself by covering it with silk, and this enabled him to coil the wire closely and to make two or more layers about the core. This had the effect of enormously increasing the strength of the magnets produced, and Henry at once recognized the importance of the discovery. But he carried the investigation much further, examining into the relation of the battery to the magnet, developing two forms of the latter, which he called "quantity" and "intensity" magnets, and by the aid of the latter succeeded in making visible and audible signals at the end of a long line, which had been declared to be impossible by Barlow.

He actually set up in the hall of the Albany Academy a line more than a mile in length, through which signals were transmitted without difficulty, and the principles involved were so well understood by Henry, that even then—in 1832—he confidently declared that transmission through any reasonable distance was possible. This system was the germ of all modern telegraphy. At about the same time its development in Europe began; but at first and for many years all European systems were based on the phenomenon discovered by Oersted—the deviation of a needle on the passage of an electric current through a conductor near and parallel to it. While Henry was exhibiting his perfectly conceived and well-executed scheme for electric transmission to visiting friends, Baron Schilling, a Russian Councillor of State, set up a model of his proposed electric telegraph before the Emperors Alexander and Nicholas, the first of the many "needle" systems which prevailed in Europe for many years, but which were finally driven out by the superior merits of the American system. Schilling's telegraph required thirty-six needles for its operation, besides a complicated device for an audible signal to attract the attention of the operator.

In connection with his study of magnets, Henry also devised what is now generally known as a "relay," which is an arrangement by means of which an electro-magnet operated by one current is made to close the circuit of another battery, thus enabling a feeble magnet, requiring only

a feeble current, to set into operation another at any point in the circuit. Thus he had evolved all the essentials of a complete telegraph system, lacking only mechanical details which engineering skill and ingenuity might easily have supplied.

Had Henry been less a lover of pure science, or had his commercial instinct been more highly developed, the Albany Academy mile of wire would have grown into the telegraph system of America, instead of furnishing, as it unquestionably did ten years later, the principle upon which that system was founded. It has required a good many years to dispel certain illusions concerning the electric telegraph to which Americans were inclined to cling, but it is now tolerably well known among intelligent people that the first commercially successful electric telegraph line was *not* erected in this country; that the telegraph can in no sense be called an American invention, although the American system has proved to be so superior that it has long ago practically superseded all others; and that by far the larger share of the credit for the success of this system is due to Joseph Henry for his discovery of the scientific principles upon which that success depended.

In the meantime Henry was engaged in further researches of the very highest importance. He sought to use the powerful magnets which he was now able to construct in the solution of a problem which had thus far baffled the efforts of the ablest electricians in Europe. Having succeeded beyond all others in *producing* magnetism by *using electricity*, he hoped to be able to successfully attack the inverse problem, the *production of electricity from magnetism*. All physicists believed that this must be possible, but no one had hit upon the method of doing it. Curiously enough, another great experimental philosopher, also a young man, had set for himself the same problem and worked persistently upon it during the month of August, 1831. During the same month Henry began a carefully planned series of experiments, which unfortunately, owing to his duties in the Academy, he was obliged to give up, not being able to return to them for nearly a year. Entirely ignorant of Henry's

plans, Faraday, on the 30th of August, 1831—a memorable day in the history of electricity—made the capital discovery of *induction*, on which practically all modern electrical development is based. Entirely ignorant of what Faraday had done, Henry again took up the subject and had the good fortune to discover the identical phenomenon in another aspect, in which it is known as *self-induction*. In the more recent advances in applied electricity, self-induction has come to be a matter of primary importance, and time has served only to magnify the value of Henry's discovery. Learning of Faraday's experiments, he was led, through their verification, to discover induction by induced currents, concerning which he made a most interesting and valuable investigation. Of his many other important discoveries in electricity there is one that must not be passed without mention. It was that the discharge of a Leyden jar was oscillatory in character, in which he anticipated Helmholtz and Lord Kelvin in the recognition of a phenomenon which has, within a very few years, come to have a deep import. The present estimate of the value of Henry's work in electricity is reflected in the following remarks, made not long ago by one of England's leading electricians: "At the head of this long line of illustrious investigators stand the names of Faraday and Henry. On the foundation-stones of truth laid down by them, all subsequent builders have been content to rest * * * * In them (the scientific writings of Henry) we have not only the lucid explanations of the discoverer, but the suggestions and ideas of a most profound and inventive mind, and which indicate that Henry had early touched levels of discovery only just recently becoming fully worked."

In the study of Terrestrial Magnetism, the great work of Bache, begun in Philadelphia and continued with important extension in the United States Coast and Geodetic Survey, of which he was the most famous superintendent, is worthy of the highest praise. The work of Rowland in electricity and magnetism has been of much importance, and especial mention must be made of his beautiful experiment in 1876, in which he showed that a magnetic needle was affected by

a rotary disk carrying an electric charge, and also of his redetermination of the value of the ohm at a later date.

It is again difficult to resist the temptation to discuss the practical applications of electrical discoveries, for in this field it may justly be said that our countrymen have outranked all others. It would be a pleasure to relate something of the labors and successes of Wallace, the pioneer in the production of strong currents by the use of a dynamo; of Brush, who first solved the problem of arc lighting; of Edison, whose ingenious inventions in duplex and multiplex telegraphy have been eclipsed by his creation of the incandescent system of electric lighting; of Bell, whose beautifully simple device for the electric transmission of human speech startled the world in 1876, and has since all but revolutionized the conduct of the ordinary affairs of life; and of others who have contributed during the last quarter of a century to put the United States far in advance of all other countries in the application of scientific discovery to the improvement of the condition of mankind.

In other departments of physics American scholars have also had their share. In sound, important researches were made by Henry, and beautiful experimental investigations were carried out by Mayer, leading to important results. In meteorology, which is physics applied to the atmosphere, the names of Espy, Loomis, Ferrel and Abbe are everywhere known. The work of the Coast Survey in Terrestrial Physics, including magnetism and gravity, is universally admitted to be of the first order. In the application of physics to astronomy, American scholars easily rank with the highest; but into these and other regions I must not go, however much drawn towards them, for, unsatisfactory as my sketch is to its author, it must be brought to an end. It has been confined entirely to work accomplished and it has not ventured to suggest what the new century has in store. Within the last ten years a new group, almost a new school of American physicists, has made its appearance. With the enthusiasm and vigor of youth, prepared by the best of training under the most favorable circumstances, great in numbers and strong in purpose, these twentieth

century philosophers may be trusted to maintain the rank won by their illustrious predecessors and to add to their country's renown by the splendor of their achievements.

But it may be well to remind them that the problems which the nineteenth century passes on to the twentieth are not all related to science, pure or applied. How to use is often as important as how to produce. In spite of the enormous increase in the production of the necessities of life and the extraordinary diminution in their cost, their acquisition by the great majority of the race still means the exhaustion of their entire stock of energy. And this condition of things is being still further intensified by a steadily increasing proportion of idle, non-productive population, an element of both weakness and danger which modern civilization has thus far been unable to throw off. For the avowed purpose of keeping the peace, the world becomes a vast military camp, and it is not easy to decide whether scientific discovery has contributed most to the prolongation and betterment of human life or to the construction of improved machinery for its destruction. The cost of a single steel-clad battleship would establish, equip and richly endow a university, and the expenditure necessary to keep it in commission would maintain an institution for original research of such capacity and proportions that its output would be a never-ending blessing to all the people. Let us hope that among the glories of the twentieth century may be the recognition of the incongruity of a beneficence which seems to be founded upon the sentiment "Whom we would help let us first kill."

ELECTRICAL SECTION.

Stated Meeting held March 21, 1899.

A PHOTOMETRIC COMPARISON OF ILLUMINATING GLOBES.

By Robert B. Williamson and J. Henry Klinck.

Sources of artificial illumination do not, as a rule, radiate light in the direction desired. It is, therefore, necessary to control the direction of radiation by the use of "distributing" globes.

Further, the radiating surface has, usually, so great an intrinsic brightness as to give an unpleasant, glaring effect. This must be corrected by the use of "diffusing" globes.

The ideal globe should have both distributive and diffusive action, the extent and character of each being determined by the nature of the source and the kind of illumination desired.

The action of a globe in modifying the intensity of the light in a given direction is in general fourfold: First, the radiations striking the inside of the globe in the given direction are partly absorbed, leaving the emergent rays lessened in intensity; second, radiations originally not in the given direction are brought into that direction by reflection; third, radiations are brought into the given direction by refraction; and fourth, a portion of the radiations absorbed by the globe are emitted again by it, and thus becomes more or less luminous over its entire surface.

The tests described in this paper were made with the object of determining the relative merits of the various globes at present available for use in connection with the Welsbach incandescent mantle. The results given do not include all the data obtained, but are those which have been selected as being of most interest.

As no satisfactory "glare" test is known at present, the investigation was confined to the effect of the distributing

properties of the globes when used in connection with the Welsbach burner.

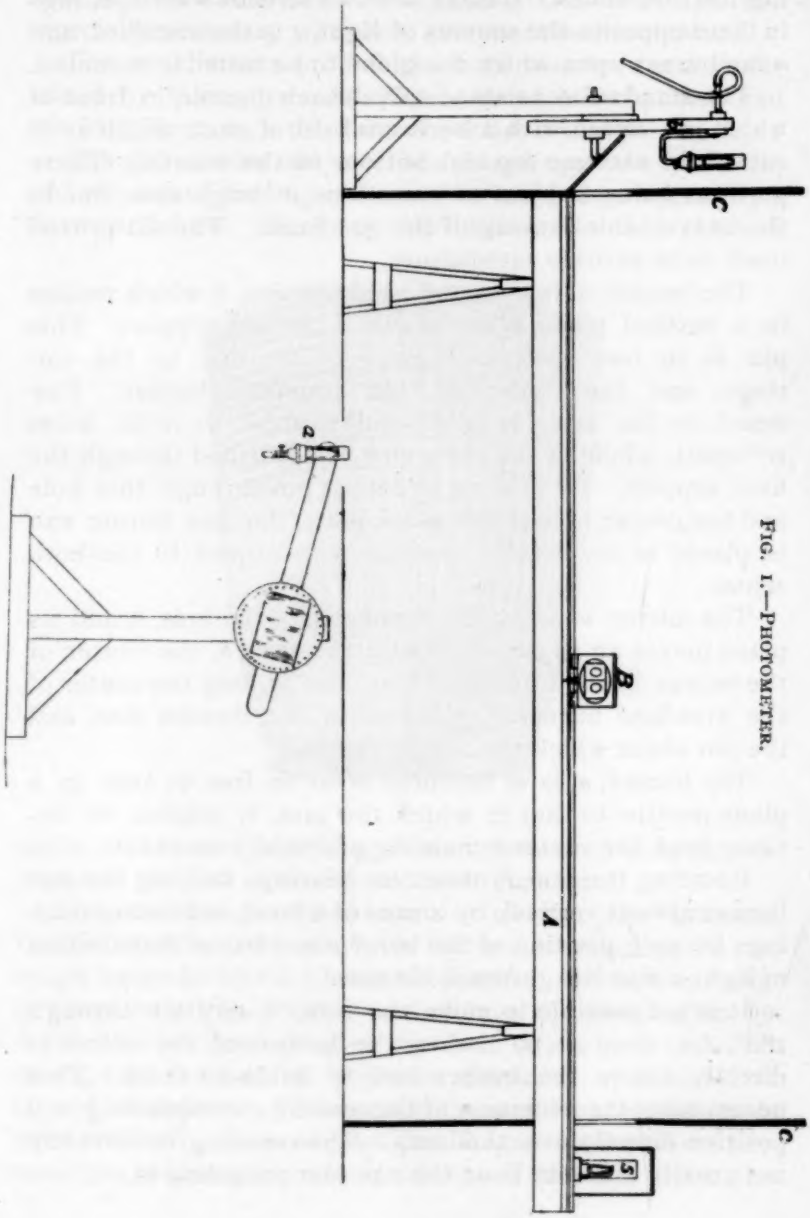


FIG. 1.—PHOTOMETER.

The tests were made by means of the Bunsen photometer.

A, *Fig. 1*, is the bar upon which the carriage, *B*, containing the disc slides. *C* and *C* are two screens with openings in them opposite the sources of light, *s* is the standard, and *a* the burner upon which the globe to be tested is mounted.

The standard consists of a Welsbach burner, in front of which is a screen with a horizontal slit of such width as to cut off the extreme top and bottom of the mantle. These portions being subject to variations in brightness, due to the unavoidable dancing of the gas flame. The slit proved itself to be entirely satisfactory.

The burner, *a*, is mounted upon an arm, *b*, which rotates in a vertical plane about a pin in a fixed support. This pin is in line with the center of the disc in the carriage, and the center of the standard burner. Fastened to the arm, *b*, is an index plate, *c*, with holes 10° apart, a hole of the same size being drilled through the fixed support. By passing a tapered pin through this hole and the proper hole in the index plate, the test burner can be placed in any desired position with respect to the horizontal.

The mirror, *m*, is rigidly connected to the arm, *b*, and its plane makes an angle of 45° with the arm, *b*, the center of the mirror being directly in the line joining the center of the standard burner, the center of the Bunsen disc, and the pin about which the arm, *b*, rotates.

The burner, *a*, is so mounted as to be free to turn in a plane parallel to that in which the arm, *b*, rotates, its distance from the center remaining practically constant.

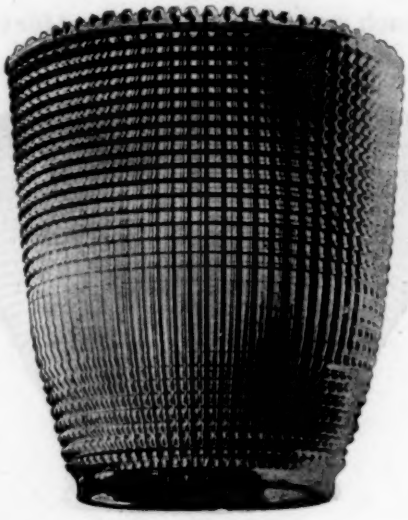
Rotating the arm, *b*, about its bearing, keeping the test burner always vertical, by means of a level, and taking readings for each position of the bar, *b*, the vertical distribution of light about the globes is obtained.

It is not possible to move the arm, *b*, entirely through 180°, for when at 90° below the horizontal the mirror is directly above the burner and is liable to crack. This necessitates the exclusion of the reading corresponding to a position directly over the lamp. This reading is certainly not greatly different from the one just preceding it.

Before obtaining the data, the mantles on the standard burner and the test burner were allowed to burn for some time to allow them to settle to a constant state; this was especially necessary whenever new mantles were used.

The distribution around the bare mantle was then obtained by taking two complete sets of observations, and checking them by a third set of partial readings.

The globe under test was then placed upon the burner, *a*, and two sets of readings taken, these being also checked by a third partial set. The bare distribution was then checked



5

again, and in case of a disagreement between the final readings and the first ones, the test was repeated.

The mantles remained quite constant, the greatest trouble experienced being with the test mantle, due to the rough usage to which it was subjected. A small opening in the mantle would widen and change the distribution so much between the taking of the bare curve and the final check, that the mantles had to be discarded upon the first sign of breakdown. When one of the mantles gave out, both were renewed. It was found that the mantle is particularly sensitive to changes in the condition of the air; when the

room was at all close it was found impossible to obtain satisfactory results. Too much ventilation, on the other hand, caused a very annoying dancing of the flame, which, when present to a small degree, was satisfactorily annulled by the slit mentioned above.

The walls of the room, the screens and bar were all dull black, as were certain spots on the floor upon which the light fell, as at the beginning trouble was experienced when reading at angles below the horizontal, owing to reflected light striking the mirror and being thrown along the bar.

The Welsbach was used as a standard for the reason that

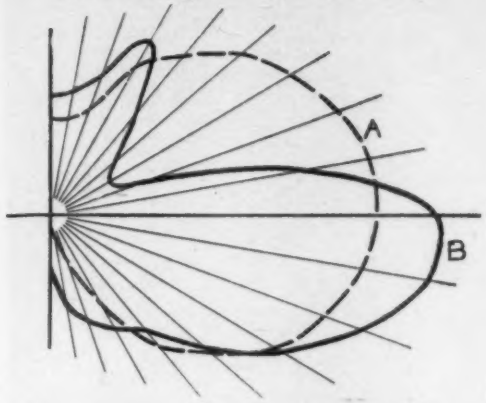
19

the Bunsen disc gives the most satisfactory results when the sources compared are identical in color. The ordinary mica chimney, commonly seen on Welsbach burners, was used throughout the entire series of tests.

Two observers were employed, one to read the photometer, the other to adjust the test burner and record the readings of the bar, as well as the position of the arm, *b*.

The globes, or reflectors, and the curves obtained from them have been given the same number in the figures to allow of easy reference from one to the other. In curve 7 is shown the distribution given by the flat, crimped, opal

No. 5.—Holophane. 1 inch = 20 c. p.



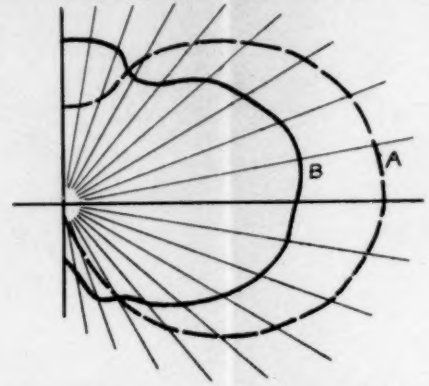
Bare lamp A.

Area above horizontal, 12·58.
" below " 11·15.
Total, 23·73.

Holophane B.

Area above horizontal, 7·92
" below " 12·72.
Total, 20·64.
Efficiency, 87 per cent.
Mean spherical, c. p., A, 46·46.
" " " B, 41·28.

No. 10.—Ground globe, egg shape, with wide flutings. 1 inch = 20 c. p.



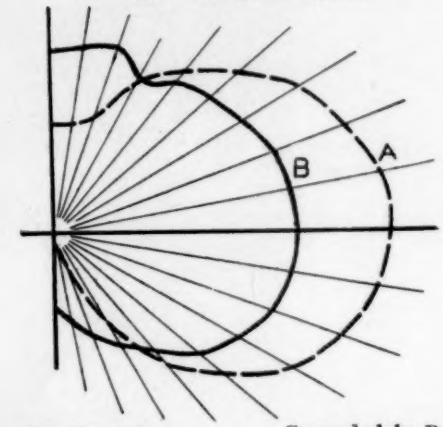
Bare lamp A.

Area above horizontal, 12·40.
" below " 10·78.
Total, 23·18.

Ground globe B.

Area above horizontal, 9·96.
" below " 8·44.
Total, 18·40.
Efficiency, 79·3.
Mean spherical, c. p., A, 46·36.
" " " B, 36·80.

No. 13.—Plain ground globe.



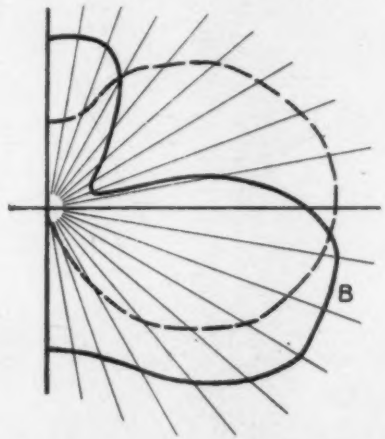
Bare lamp A.

Area above horizontal, 12·07.
" below " 11·4.
Total, 24·1.

Ground globe B.

Area above horizontal, 9·95.
" below " 9·95.
Total, 1·95.
Efficiency, 80·9.
Mean spherical, c. p., A, 48·2.
" " " B, 39.

No. 7.—Opal reflector. 1 inch = 20 c. p.



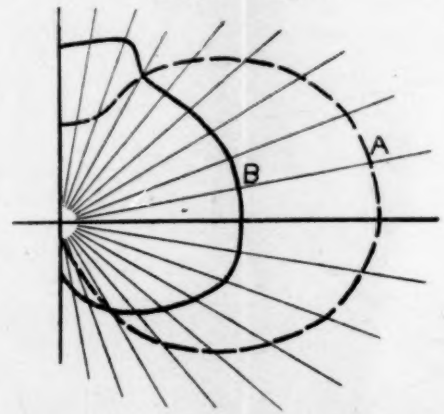
Bare lamp A.

Area above horizontal, 6·41.
" below " 14·20.
Total, 20·61.
Efficiency, 86·8 per cent.
Mean spherical, c. p., A, 46·46.
" " " B, 41·22.

Opal reflector B.

Area above horizontal, 12·58.
" below " 11·15.
Total, 23·75.

No. 11.—Plain opal globe (egg shape). 1 inch = 20 c. p.



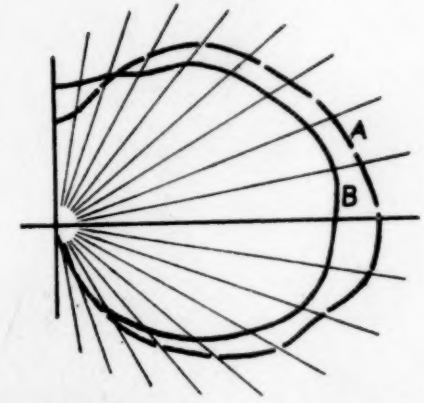
Bare lamp A.

Area above horizontal, 12·40.
" below " 10·78.
Total, 23·18.

Opal globe B.

Area above horizontal, 8·68.
" below " 7·21.
Total, 15·89.
Efficiency, 68·5 per cent.
Mean spherical, c. p., A, 46·36.
" " " B, 31·78.

No. 16.—Egg shape globe (light opalescent). 1 inch = 20 c. p.



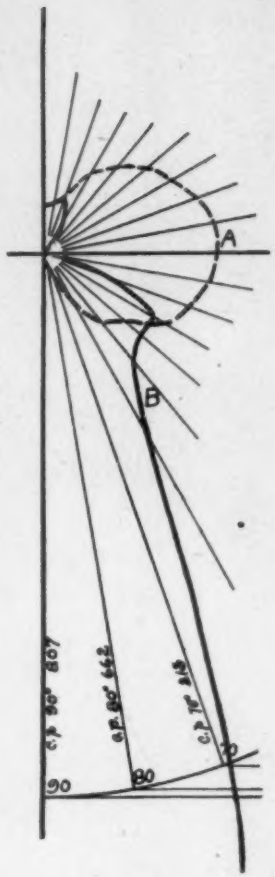
Bare lamp A.

Area above horizontal, 11·00.
" below " 9·60.
Total, 20·60.

Globe B.

Area above horizontal, 10·12.
" below " 8·48.
Total, 18·60.
Efficiency, 90·2 per cent.
Mean spherical, c. p., A, 41·20.
" " " B, 37·20.

No. 15.—Conical mirror reflector.



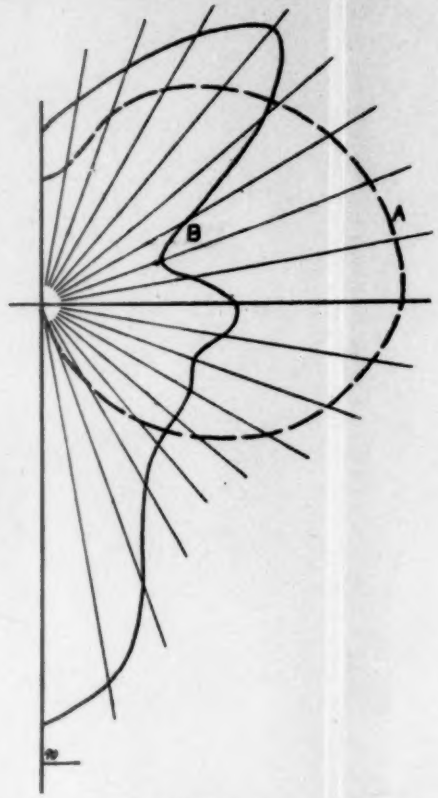
Bare lamp A.

Area above horizontal, 6·20.
" below " 5·52.
Total, 11·72.

Lamp, with reflector B.

Area above horizontal, ·62.
" below " 8·14.
Total, 8·76.
Efficiency, 74·7 per cent.
Mean spherical, c. p., A, 46·88.
" " " B, 35·04.

No. 19.—Holophane.



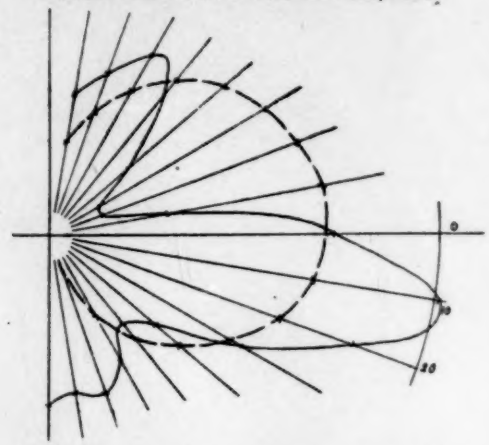
Bare lamp A.

Area above horizontal, 16·66.
" below " 12·38.
Total, 29·04.

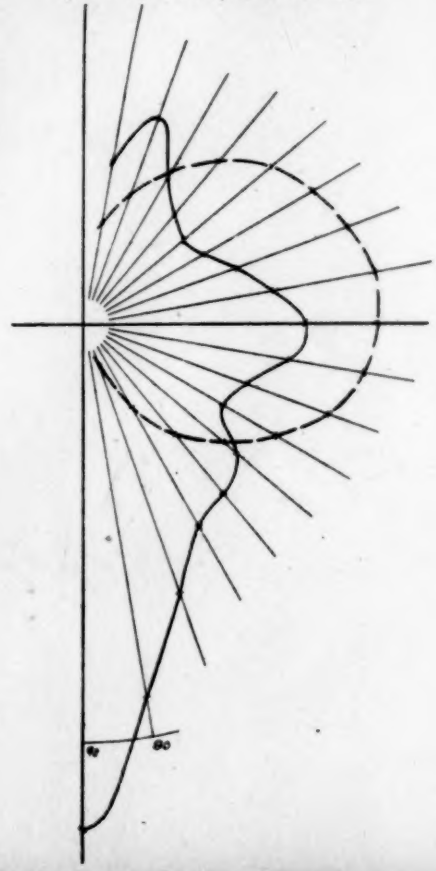
Holophane B.

Area above horizontal, 11·9.
" below " 10·52.
Total, 22·42.
Efficiency, 77·3.
Mean spherical, c. p., A, 58·08.
" " " B, 44·84.

No. 24.—Holophane, wide tulip, made from same tool as No. 20 surface, fired.



No. 27.—Holophane, pear-shaped holophane for vertical distribution.



reflector commonly used with the Welsbach mantle. (In the illustration the reflector is shown mounted upon a beaker.) The bare curve is shown by the *broken line, A*, and the distribution with reflector by the *full line, B;* this convention is used in all the curves.

From curve 7 it can be seen at once that not only is the light directly under the burner enormously increased, but that an increase occurs at almost every point below the horizontal. The large loop at the top in this, and the other curves, is due, in part, to the light which escapes through

24

the necessary opening in the top of the reflector, or globe, and in part to the light diffused by the globe. In the use of this reflector there is but one disadvantage apparent, that is, the glare of the mantle itself is not in any way reduced; this can be done with this reflector to a degree by the use of the small ground glass cup which is sometimes placed at the base of the chimney.

Globes 8, 9, 10, 11 and 16 all have the shape shown in illustration 16.

Curve 10 is from an egg-shaped globe of ground glass, the

fluting being inside and out, and being three times as wide as in globe 8. This curve shows an increase directly above and below the burner which would be noticeable under ordinary conditions. The absorption between 60° above and 60° below the horizontal is quite marked.

Curve 11 is from an egg-shaped globe of plain opal and is noticeable only for the large amount of absorption shown, the diffusion being, of course, the redeeming feature of this globe.

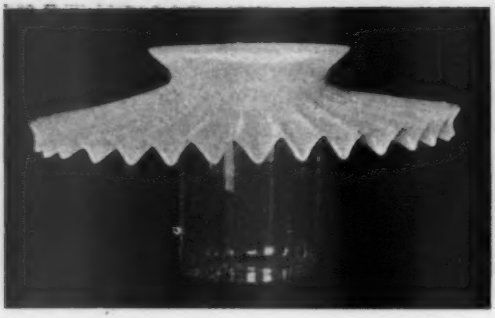
Curve 16 is from an egg-shaped globe of fluted opalescent glass, the fluting being both vertically and spirally.

27

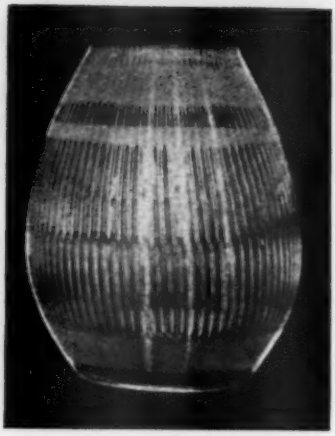
Globes 12, 13 and 17 are all of the shape shown in illustration 17.

Curve 13 is from a spherical globe of ground glass and shows its diffusive action by increasing noticeably the amount of light directly above and below the burner.

Curve 17 is from a spherical globe, the upper portion of which is ground, the lower being clear. The curve shows diffusive action upwards, although apparently designed to reflect the light downwards.



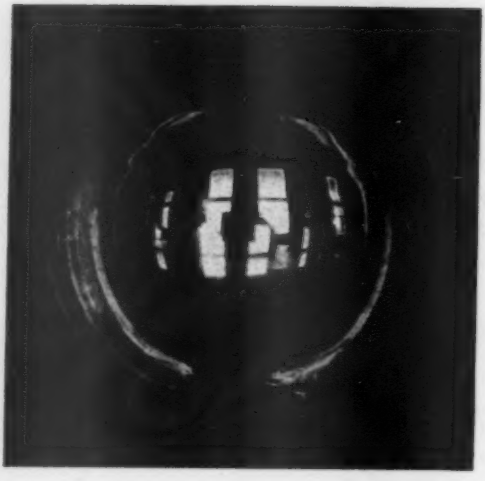
7



8

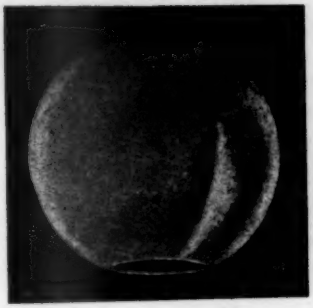
9

10



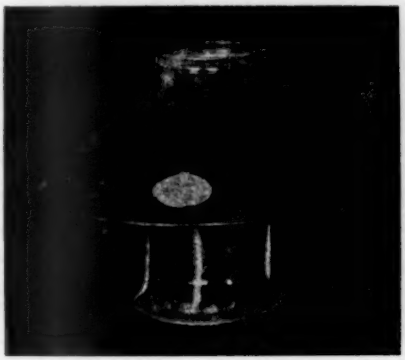
12

11

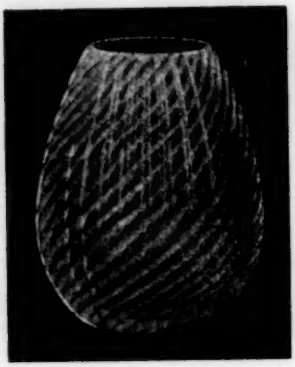


13

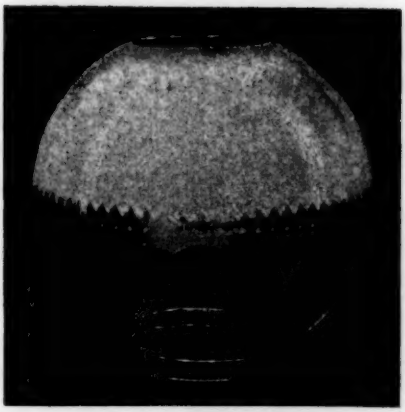
14



15



16



17

Curves 14 and 15 are from mirror reflectors, shown in illustration 15. They are constructed of a number of segmental pieces of mirror glass held in position by means of a metal backing. Curve 14 is from a nearly flat mirror reflector. The light is thrown down and concentrated between 20° and 70° below the horizontal, the amount directly under the burner being very small.

Curve 15 is from the reflector shown (supported on a beaker) in illustration 15, the mirrors in this case making an angle of 45° with the horizontal. As a means of obtaining a brilliant illumination in a small space, this reflector gives the best results of any of those upon which data were obtained.

Curves 5, 19, 24 and 27 were obtained from "Holophane" globes. These globes consist of clear glass, with vertical ribs on the inside, and horizontal ribs on the outside. The inner ribs are all similar in shape, and the outline is that of a sine curve. The outer ribs vary in shape with the service for which the globe is designed, being simply prisms in the case of 19 and 27, and varying in outline in 5 and 24.

The general principle of construction being to refract or reflect the ray, from a region where it would be wasted to the point at which it is desired to use it.

Curve 5 is from a globe intended for nearly horizontal distribution.

Curve 19 is from a globe intended for street lighting, or general illumination, the major portion of the light being thrown below the horizontal.

Curve 27 is from a globe similar to 19, except for an added top portion. This curve has a higher maximum reading than 19. This, however, is not due to the top entirely, but to the fact that the globe had been "fire-polished," that is, heated enough to cause the surface to glaze over, and remove all traces of the mould. A globe similar in design to 19, but which has been fire-polished, gives a maximum reading very nearly equal to 27.

The selected results in this paper are offered as examples of the performance of the various types of globes available for use with the Welsbach mantle. They show that a

globe, or reflector, must be designed with due regard to the service expected of it.

No highly ornamental or decorated globes were tested, since these are used as a rule under conditions in which efficiency of illumination is not important, this being, in fact, of secondary consideration as compared with the artistic effect.

DEPARTMENT OF PHYSICS AND ELECTRICAL ENGINEERING,
THE LEHIGH UNIVERSITY, March, 1899.

NOTES AND COMMENTS.

COST OF GOOD ROADS AND LOSS FROM BAD ROADS.

In a paper read before the Engineers' Club of Philadelphia, recently, Gen. Roy Stone, Director of the Office of Road Inquiry in the United States Department of Agriculture, discussed "Various Phases of the Road Question," says *Municipal Engineering*. From data obtained from over 10,000 letters of inquiry, General Stone deduced certain figures, referring to the average length of haul from the farms to market or shipping points, the average weight of load hauled and the average cost per ton for the whole length of the haul. The figures, tabulated, are as follows:

GROUP OF STATES.	Average Haul, Miles.	Average Weight, Pounds.	Average Cost Per 2,000 Pounds Per Mile.	Total Average Cost Per Ton for Whole Length of Haul.
Eastern	5·9	2,216	$0 32	$1 89
Northern	6·9	—	27	1 86
Middle	8·8	—	*31	*2 72
Cotton	12·6	1,397	25	3 05
Prairie	8·8	2,409	22	1 94
Pacific Coast and Mtn.	23·3	2,197	22	5 12
Whole United States	12·3	2,002	25	3 02

* Middle Southern States.

Assuming the correctness of the data, and using the census return of farm products and forest and mineral outputs, and estimating incidental traffic, General Stone arrives at a total of 313,349,227 tons as representing the total annual movement over country roads. At the average cost, $3.02 per ton, the grand annual cost of haulage on public roads amounts to $946,414,665. Not including the loss of perishable products for want of access to market when

prices are good, and the uselessness of cultivating certain products which depend upon the markets being always accessible, statistics of the cost of operating foreign highways, and the data obtained from the use of the few good roads existing in this country, would indicate that nearly two-thirds of the above cost is directly chargeable to bad roads. The enforced idleness of men and horses during a large part of the year is another item which should be charged largely to bad roads. The negative or hostile attitude of the rural population toward all effective legislation in this direction is an obstacle also to road improvements in this country, while another is the general overestimate of the cost of such improvement.

A few years ago the macadam roads of New Jersey cost $10,000 per mile; now equally good roads are being built for $3,000. even where railway transportation of material is required; and in localities better supplied with road material, and where a narrower road is deemed sufficient, $1,500, or even less, will make a mile of good stone road. Experience has demonstrated the fact that in most country districts a single stone road, 8 or 10 feet wide, with a good earth road on one or both sides, is more generally satisfactory than a wider road of macadam.

An interesting German inven ion provides for instantaneous soda water in siphons. The device is called "sodor." It consists of a siphon provided with a wicker covering. The top is of peculiar construction, and admits of the insertion of a pear-shaped, thin iron capsule, filled with liquid carbon dioxide gas. The top of the siphon is hinged, and after it is swung into place a lever is pushed down which forces a piercing pin through the "sodor" capsule. The gas then forces its way out through special channels into the top of the siphon and impregnates the water in the siphon. The thick walls of the bottle are not readily broken by the pressure of the gas. This device will undoubtedly prove of considerable interest to those who live at a distance from bottling establishments.

The question as to the best means of isolating a freezing mixture is one of considerable practical importance in chemical and physical work. In a recent number of the *Berichte*, Prof. W. Hempel describes a series of comparative experiments undertaken by him to settle which substance was most suitable for ordinary work. Starting with a temperature of about — 75° to — 80° C., produced by solid carbon dioxide and ether, the rate of rise of temperature with time was measured, and, as a result, eiderdown was found to be the best insulator, wool carefully dried at 100° C. being nearly as good, and having the advantage of cheapness. Three samples of vacuum tubes, of the pattern invented by Professor Dewar, were also tried, and were found to give very varying results amongst themselves, and all being much inferior in insulating power to either eiderdown or cotton wool. Thus with eiderdown a rise of 12° C. occurred in eighty-eight minutes, with dry wool a rise of 20° to 24° C. in the same time, whilst the three vacuum-jacketed tubes gave under the same conditions rises of 65°, 69° and 39° respectively. The results would seem to show that trustworthy Dewar tubes cannot be bought commercially.

A SURFACE-CONTACT SYSTEM FOR ELECTRIC STREET RAILWAYS.

At the last British Association meeting, Prof. Silvanus P. Thompson and Mr. Miles Walker presented a joint paper, describing a system of transmitting an electric current to a street car motor by means of metallic studs placed at intervals in the roadway, contact being made between the conductor—which is underground—and the motor on the car by means of a sliding shoe or skate of sufficient length so as to be in contact with two studs at once.

From the account of the system in the *English Mechanic*, the authors claimed that this system would obviate the use of the overhead wire used in the trolley system, and also the continuous slot in the roadway which is necessary with the underground conduit system. There could be no danger to pedestrians from electric shock in crossing the road and stepping on the studs, for these could only be energized and the current set up by contact with the skate under the motor car.

INDUSTRIAL COLOR PRINTING.

A machine has been introduced into England for printing in colors which, says *Engineering*, is in its operation a departure from any machine hitherto used for a like purpose. It is the invention of Ivan Orloff, chief engineer and manager of the Russian Government Printing Works, at St. Petersburg, and it possesses many points of interest. In the ordinary flat color printing machine the successive colors are applied one at a time as each one becomes dry, but the Orloff machine puts down all the colors on the paper at once, so that a great saving of time is effected.

The principle of the machine is as follows: The blocks which take the different colors are fixed to a cylinder of large diameter, and each block receives the supply of colored ink intended for it, and as the cylinder revolves the ink on each block is transferred to a composition roller very similar to an ordinary inking roller. After all the colors have been transferred to this roller, each in its proper position, an engraved block or form follows and receives a perfect impression from the composition roller.

Thus impressed, the form passes on and comes in contact with the paper on the impression cylinder, where it prints all the colors at one operation. The whole of these varied transfers are performed during one revolution of the cylinder. While the blocks pass under the inking rollers the latter are, at the proper time, lowered by a system of cams so as to come into contact with the blocks which they are intended to ink. The number of colors that can be used is only limited by the number of blocks and the size of the machine. All the operations go on continuously, as the cylinder revolves in one direction only. The number of finished impressions is stated to be about 1,000 an hour. The machine was originally designed for the Russian Government to print multi-colored patterns for bank notes, and it appears to be well adapted for this purpose.

Franklin Institute.

(*Proceedings of the Stated Meeting held Wednesday, December 20, 1899.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 20, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 113 members and visitors.

Additions to membership since last report, 45.

The following gifts were reported:

A portrait in oil of the late Isaac P. Morris, for many years prominently identified with the Institute, presented by John T. Morris; an American flag of spun glass, made and exhibited at the glass works on the esplanade of the National Export Exposition, from Messrs. Gillinder & Sons, Inc.; specimens of rose quartz, from the Bridgeport Wood Filler Company; specimens of aluminum and Dutch metal foil, from the Sayre Metal Company; a number of chilled cast-iron balls, from the Cayuta Wheel and Foundry Company; specimens of slate from the Slatington-Bangor Slate Syndicate; specimens of iron ore, dolomite and limestone, from the Virginia Coke, Coal and Iron Company; an ornamental slab, cut with a pneumatic tool, from the Chicago Pneumatic Tool Company; and samples of steel for tools and dies, from the Crescent Steel Company.

The Secretary was directed to make proper acknowledgment of the gifts, with the thanks of the Institute.

Acknowledgment of election as an honorary member of the Institute from Mr. Chas. Kirchhoff, of New York, was read by the Secretary.

The following nominations were made:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	THEO. D. RAND.
" *Secretary*	(" one year)	WM. H. WAHL,
" *Treasurer*	(" ")	SAMUEL SARTAIN.
" *Auditor*	(" three years)	WM. O. GRIGGS.

For *Managers* (to serve three years).

ARTHUR BEARDSLEY,	H. W. JAYNE,
HENRY C. BROLASKY,	LAWRENCE T. PAUL,
JAMES CHRISTIE,	HORACE PETTIT,
F. LYNWOOD GARRISON,	OTTO C. WOLF.

For *Members of the Committee on Science and the Arts* (to serve three years).

HENRY F. COLVIN,	JOHN M. HARTMAN,	LOUIS E. LEVY,
THOS. P. CONARD,	CHAS. C. HEYL,	TINIUS OLSEN,
GEO. S. CULLEN,	H. R. HEYL,	LUCIEN E. PICOLET,
CHAS. DAY,	GEO. A. HOADLEY,	GEO. F. STRADLING,
ARTHUR FALKENAU,	HARRY F. KELLER,	W. F. WILLCOX.

The paper of the evening was then announced.

"The Tower Clock in the City Hall, Philadelphia," by Mr. Warren S. Johnson, of Milwaukee, Wis., the designer and constructor. The speaker in-

troduced the subject by a reference to a number of the most notable clocks erected for public service, and proceeded to the description of the details of the Philadelphia instrument, illustrating the subject with the aid of numerous lantern slides. (Referred for publication.)

The President expressed the thanks of the meeting to the speaker for his lucid description of an apparatus of much local importance.

Mr. Louis E. Levy described and exhibited in operation an improved form of his acid-blast apparatus for etching metal plates, first shown at the stated meeting of February, 1899. The more important improvements relate to provision for preventing the heating of the acid, thus enabling higher blast pressure to be used, and increasing the rapidity of the etching process, and in employing aluminum in the construction of the entire apparatus. The apparatus, as now built, affords an interesting example of the indifference of this metal to the continued action of dilute nitric acid.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of the proceedings of the stated meeting held Wednesday, December 6, 1899.*]

PROF. EDGAR MARBURG in the chair.

The following reports were adopted :

Pocket Recorder for Tests of Materials. Gus. C. Henning, New York.

This report, of which an abstract appears in the *Journal* for December, was amended in certain particulars, and the applicant was awarded the Edward Longstreth Medal of Merit.

Drawing Tables. Samuel J. Laughlin and James Hough, New York.

ABSTRACT.—The invention is secured by letters-patent of the United States to the applicants, No. 550,413. The apparatus consists essentially of a drawing-board across whose surface a straight-edge or ruler is arranged to move into positions always parallel to itself. With these essentials are combined devices for adjusting the drawing-board or the paper, to facilitate the plotting of angles or the measurement of lines in all kinds of instrumental drawing.

The special features of these instruments cannot be explained without the aid of diagrams.

The finding of the investigating committee is stated in the following terms : " In view of the originality displayed in devising a parallel-moving straight-edge and rotatable drawing-board, and the excellence of their operation, in combination with other time-saving devices as applied in the Laughlin-Hough drawing tables," the award of the John Scott Legacy Premium and Medal to the inventors. [*Sub-Committee.*—L. F. Rondinella, Chairman ; J. Logan Fitts.]

Street Railway System. Andrew McGill, Dunedin, New Zealand.

The inventor's proposition is to construct a conduit of sufficient capacity to receive the truck and running-gear of an electric or cable car, having a

slot at the street surface to communicate with the same. Attached to this truck, and passing through the slot, are thin, wide bars, of sufficient cross-section to support the body of the car above. Special provision is made to facilitate passage around curves.

The investigating body believes that the disadvantages of inaccessibility to the truck mechanism, especially in the case of electric railways, where prompt access to the motors and their connections is of the highest importance, would more than offset the advantages claimed for the invention. [*Sub-Committee.*—James Christie, Chairman; Francis Head.]

Apparatus for Generating Acetylene Gas. Eugène Bournonville and Joseph N. Goldbacher, New York City.

ABSTRACT.—This apparatus belongs to the class of drop machines, *i. e.*, in which the calcium carbide is automatically fed in small quantities into relatively large quantities of water, the dropping device being actuated by the downward motion of the bell of the gasometer connected with the apparatus.

The apparatus is covered by letters-patent of the United States granted to applicants.

Reference is made to these for details of construction, which could not be made intelligible without illustrations.

The report speaks approvingly of the merits of design and mechanical arrangement embodied in the machine. [*Sub-Committee.*—Charles A. Hexamer, Chairman; Harry F. Keller.]

The following reports passed first reading:

Nut-locking Washer. James Walsh, Jr., Philadelphia. [An advisory report.]

System of Ventilation. Geo. W. Yearicks, Philadelphia. [An advisory report.]

System of Oil-heating and Incandescent Lighting. Arthur Kitson, Philadelphia.

Method of Recording and Reproducing Sound. Thomas H. MacDonald, Bridgeport, Conn.

The last two reports were held over for final action until the next stated meeting.

W.

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, held Tuesday, December 19, 1899. Vice-President Dr. W. J. Williams in the chair. Present, thirty-nine members and visitors.

The nomination of officers for the ensuing year was referred to a special committee to report at the next stated meeting.

Dr. Henry Leffmann read the paper of the evening, on "Artesian Waters." The author gave a brief historical sketch of the subject, which was followed by reference to the chemical character of numerous artesian waters from wells in the region about Philadelphia.

Mr. Louis Woolman supplemented the previous speaker's remarks with an elaborate account of the various water horizons of the coastal plain of the Eastern United States. Mr. Woolman illustrated his remarks with the aid of charts, lantern slides, and microscopic slides exhibiting various forms of diatoms and foraminifers found in the strata penetrated in sinking such wells in the region above named.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, December 9, 1899. President James Christie in the chair. Present, twenty-six members and visitors.

The papers of the evening were read by Mr. Edward K. Landis, on "The Tilly Foster Mine," and by Dr. H. M. Chance, on "Some Problems in Deep Coal Mining, with a Description of some New Methods." After some discussion, both papers were referred to the Committee on Publications.

ELECTRICAL SECTION.—*Stated Meeting*, held Friday, December 22d. Prof. Geo. A. Hoadley, President, in the chair. Present, forty-four members and visitors.

The subject for discussion was "Automobiles," and was opened by Mr. Pedro G. Salom.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, December 14, 1899. President Wilfred Lewis in the chair. Present, forty-two members and visitors.

The subject for discussion was "Internal Combustion Engines." The President opened the discussion with a description of the Diesel Motor Among the points that received attention in the discussion which followed were that of ignition before complete compression; the weight and volume of this class of engines as compared with steam engines of equal power; the time duration of firing a charge; and the rate of increase in pressure at the moment of explosion.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, held Friday, December 8th. Prof. Geo. F. Stradling in the chair.

Professor Stradling read a communication "On the Loudness of Sound," which was freely discussed.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.—*Stated Meeting*, held Tuesday, December 5th. Dr. Henry Leffmann in the chair. Present, twenty-two members and visitors. A number of dry plates which had been in possession of Dr. Himes since the year 1884 were presented by him, with the suggestion that they be tested by the members.

Mr. John G. Baker, member of the Branch, exhibited and described an improved device for holding squegee and other dry plates in mounting.

The discussion of the evening, on "Apparatus and Appliances for Microscopy and Photography," was opened by Mr. Fred. E. Ives, who described a number of microscopic accessories which were on exhibition.

A motion was passed directing the Executive Committee to formulate a plan to be presented to the Chemical Section which would secure to the Branch fuller and more independent action. Consideration of the subject was deferred until the Committee should have made its report.